

UNITED STATES AIR FORCE  
ARMSTRONG LABORATORY

**Wastewater Treatment Plant  
Environmental Study Final Operations  
and Maintenance Manual, Shaw Air  
Force Base, South Carolina**

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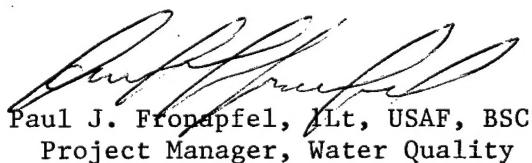
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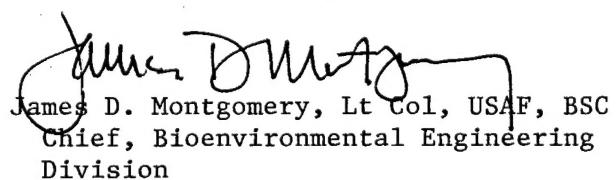
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## **CHAPTER 1**

### **INTRODUCTION TO THE SHAW AIR FORCE BASE**

### **WASTEWATER TREATMENT SYSTEM**

#### **1.1 INTRODUCTION**

This volume has been prepared for the operations and maintenance staff for the purpose of successfully operating the Shaw Air Force Base wastewater treatment plant (WWTP). This manual is intended to serve both as a training resource and as a routinely used guide to assist in the day-to-day operation and maintenance of the treatment facility.

The specific purpose of this manual is to provide the information necessary for plant personnel to make proper decisions that will ensure successful operation of the plant. This manual fulfills this goal by: (1) acquainting personnel with the overall capabilities of the equipment; (2) instructing them on the purpose and intended operation of each process; and (3) providing them with the necessary instructions for the proper operation and maintenance of the facility.

The chapters of the O&M Manual are an attempt to provide complete and straightforward descriptions of the fundamental concepts related to the treatment facility. It is hoped that through frequent and routine use of the manual, plant personnel will become thoroughly familiar with the fundamentals presented and will be able to identify problems and determine a course of action for their solution. No manual, however complete and well prepared, can replace good judgment on the part of plant personnel in ensuring successful operation of the wastewater treatment facility. There are far too many possible problems and situations that the operations and maintenance staff will have to face for any such document to cover them all in detail.

The organization of this material is intended to make it easy to find desired information and keep it up to date. The format and use of a numerical outline will allow selected portions of the manual to be easily revised and updated. New chapters can be added or existing chapters expanded without affecting the remainder of the document. No manual written without the benefit of actual operating experience and input from the plant operators will be either complete or entirely correct. It is hoped that these chapters will be periodically updated to keep them current and maintain their usefulness. Review

and comments from the plant operating personnel are essential to the usefulness of the O&M manual.

Operators should also utilize other resources available to them when making operational decisions. These include plans and specifications, vendor supplied materials, and relevant training materials. References to these materials will be made throughout the O&M manual.

## 1.2 GENERAL PROCESS DESCRIPTION

The Shaw AFB wastewater treatment plant is a biological treatment system employing the activated sludge process to achieve secondary treatment levels. The plant employs primary and secondary treatment processes, sludge stabilization, and sludge dewatering processes. The treatment plant is designed to treat an average daily wastewater flow of 1.2 million gallons per day (MGD). The treatment plant's most recent major modification was completed in March 1994.

### 1.2.1 Major Treatment Units

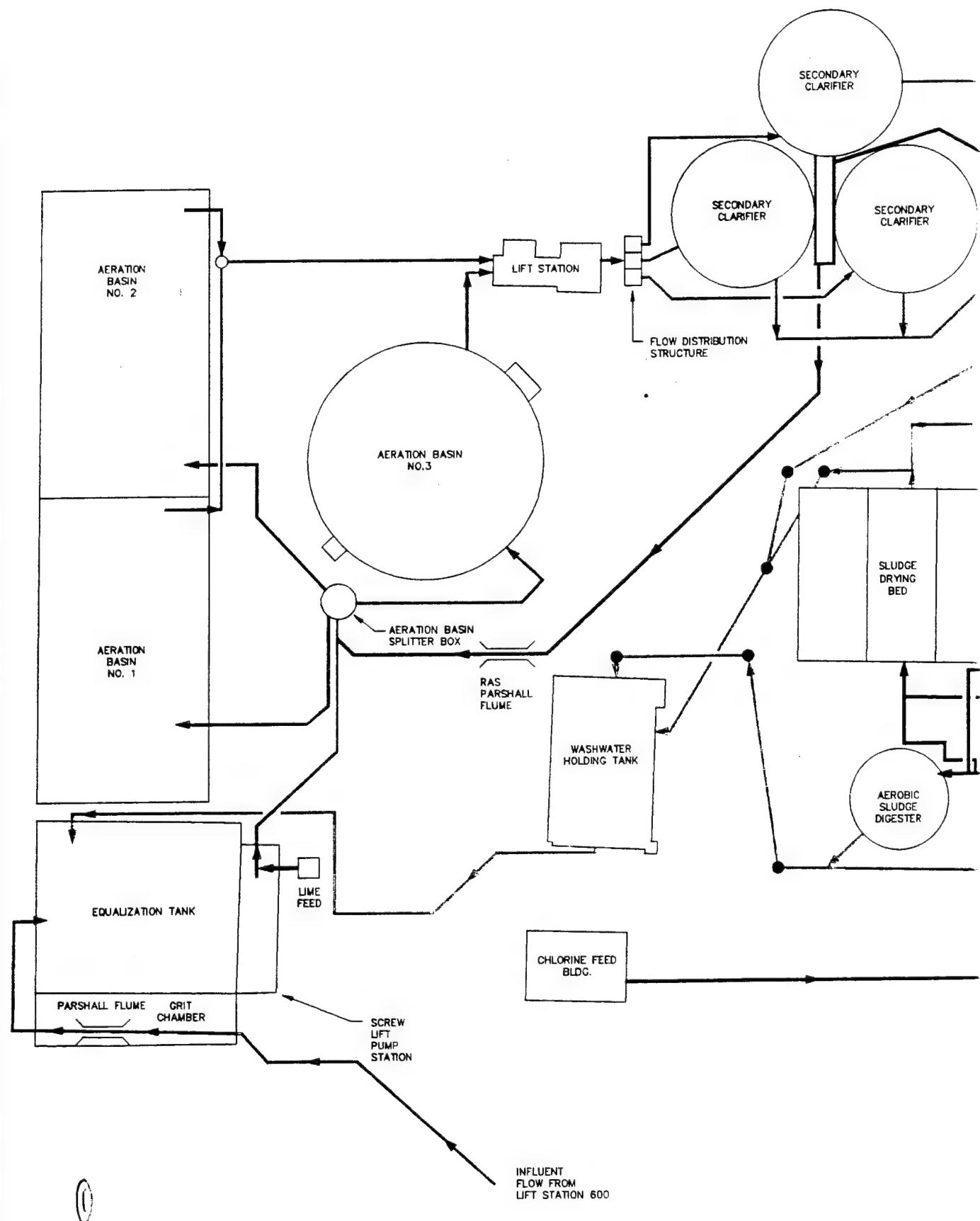
The major treatment units at the Shaw AFB wastewater treatment plant are:

- Screening
- Grit Removal
- Biological Treatment (Activated Sludge)
- Secondary Clarifiers
- Multi-Media Filtration
- Aerobic Digesters
- Drying Beds
- Lime Stabilization of Liquid Sludge
- Sludge Land Application
- Disinfection (Chlorination)
- Dechlorination

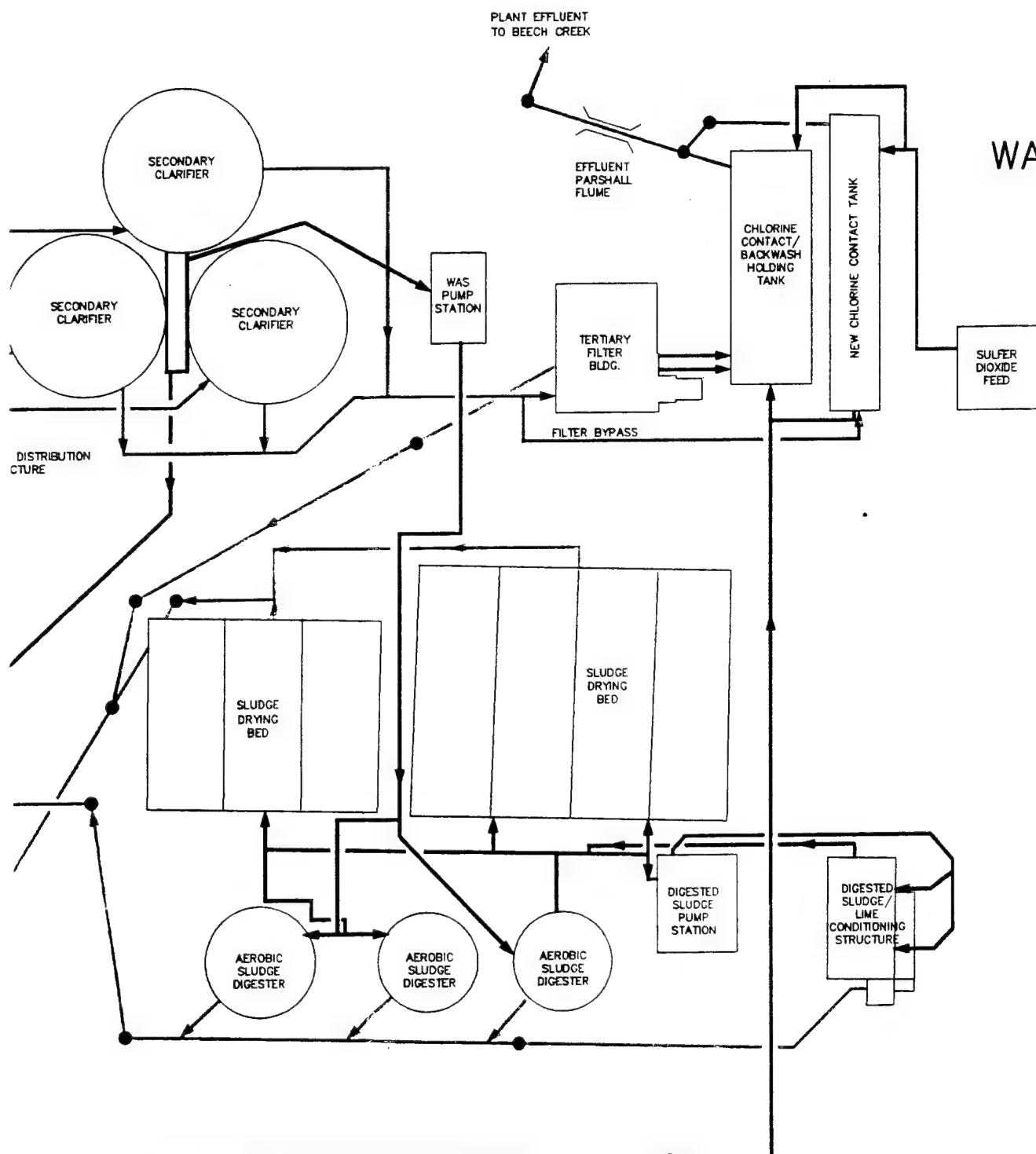
Figure 1.1 presents a flow schematic of the Shaw AFB wastewater treatment plant. Major unit processes and flow streams are identified in the schematic.

In addition to the wastewater treatment plant, the operations and maintenance staff are responsible for the operation of twelve lift stations located throughout the Shaw AFB. These lift stations are identified and located as follows:

- Station No. 0012 Shaw Drive Pumping Station
- Station No. 0116 Aero Club Lift Station
- Station No. T-28 Mobile Communications Bldg. Lift Station



FLOW SC  
SHAW  
WASTEWATER  
PL

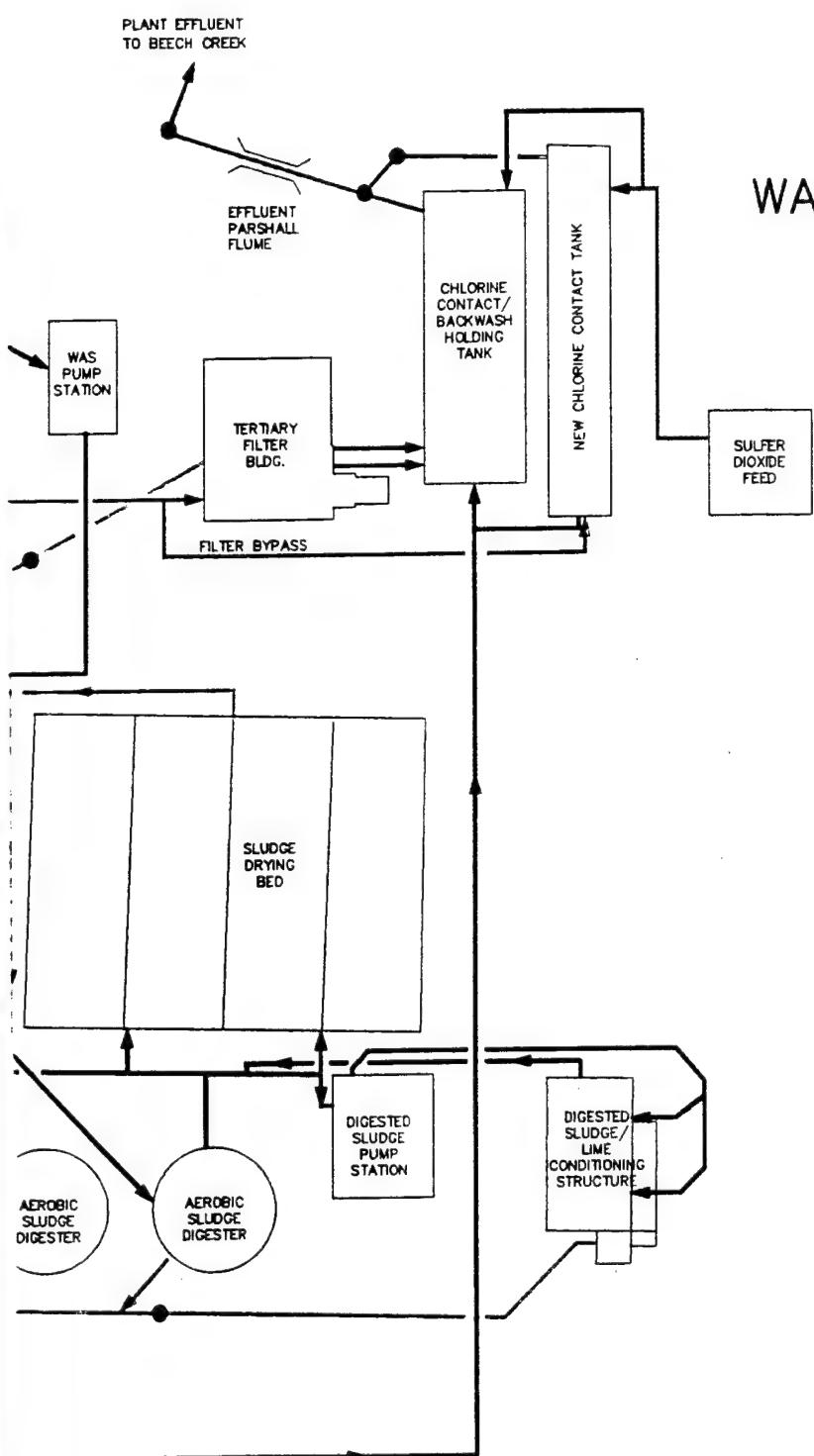


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**FLOW SCHEMATIC  
SHAW A.F.B.  
WASTEWATER TREATMENT  
PLANT**



**LEGEND**

- PLANT FORWARD FLOW
- SLUDGE FLOW
- CHEMICAL FEED
- BACKWASH/SUPERNATANT/UNDERDRAIN

- Station No. 600 Main Lift Station
- Station No. 600 Old Main Lift Station
- Station No. 1130 9th Air Force Lift Station
- Station No. HQ Headquarters
- Station No. 1216 Aircraft Maintenance Lift Station
- Station No. 1600 AGE Maintenance Lift Station
- Station No. 3227 Old Wherry Housing Area Lift Station
- Station No. 5630 New Wherry Housing Area Lift Station
- Station No. 0306 WWTP Influent Pump Station

## **1.3 OPERATOR AND MANAGEMENT RESPONSIBILITY**

### **1.3.1 Operator Responsibility**

Great sums of public funds have been invested in many large and complex wastewater treatment facilities to meet the discharge requirements necessary to maintain and protect the environment. Because of their function, the wastewater treatment plant operators play a key role in pollution control. Without efficient operation of each facility, the research, planning, and construction that has been done to accomplish the goals of water quality control will be wasted. Thus, the treatment plant operator can make the difference between pollution control equipment which is performing just adequately or excellently. Operators have a very responsible and important position since they are the only ones who control how well the wastewater will be treated before it is discharged into the environment.

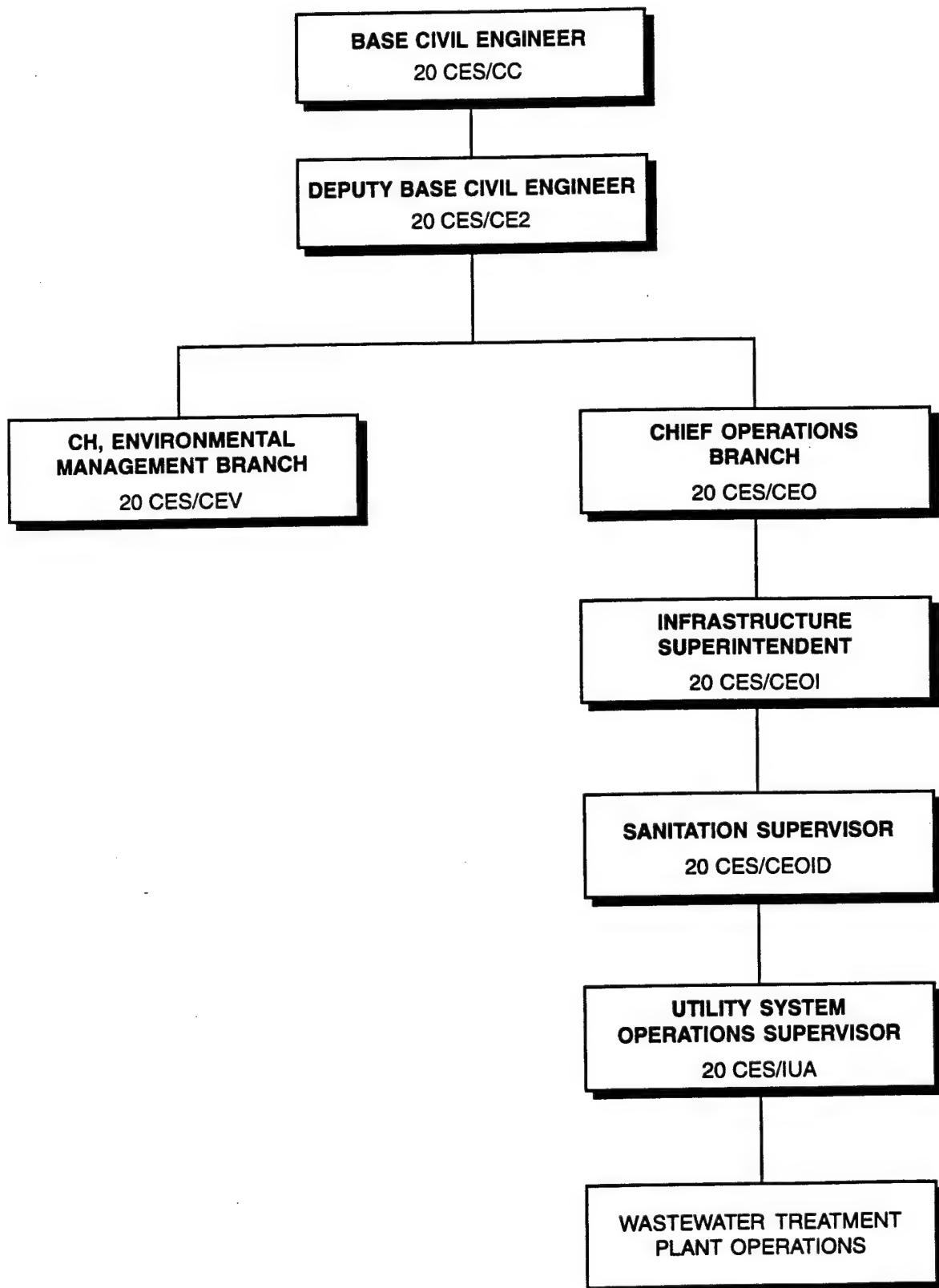
The Shaw AFB operators are responsible for the overall operation and maintenance of the WWTP. Their duties encompass all activities of the WWTP and in other areas, such as lift stations and swimming pools and water treatment units.

### **1.3.2 Management Responsibility**

Management of the Shaw AFB wastewater plant, including the Chief of the Operations Branch of Civil Engineering, Infrastructure Superintendent, Non-Commissioned Officer-in-Charge (NCOIC), and Utility Operations Supervisor have responsibility for providing administrative and supervisory control over the operation and maintenance of the treatment system. These responsibilities include supervisory direction, personnel management, and coordination with other on-base support services. Management is also responsible for ensuring effective communication among all personnel, encouraging operational suggestions, and marshaling the necessary resources for needed projects at the WWTP. Figure 1.2 provides an organization chart for the Shaw AFB WWTP.

Figure 1.2

## SHAW AFB WWTP ORGANIZATIONAL CHART



## 1.4 OPERATOR TRAINING AND SELECTED REFERENCE MATERIALS

There are no formal training programs available for the military operators at the Shaw AFB WWTP. On-the-job training is the primary training mechanism used.

To enhance a self-study program, a number of more advanced materials specific to the Shaw AFB wastewater treatment plant should be obtained for use by the operators. Recommended references from the Water Environment Federation (former Water Pollution Control Federation) include:

- *Manual of Practice 7--Operation and Maintenance of Wastewater Collection Systems*
- *Manual of Practice OM-3--Plant Maintenance Program*
- *Manual of Practice MOP-16--Anaerobic Sludge Digestion*
- *Manual of Practice 11--Operation of Wastewater Treatment Plants*
- *Manual of Practice OM-1--Wastewater Sampling for Process and Quality Control*

In addition to the above self-study materials, it is recommended that the following approaches to operator training be adopted at the Shaw AFB wastewater treatment plant:

- An in-house training program utilizing plant personnel and base resources focused on specific plant processes and treatment-related subjects should be adopted. Classes should be held on at least a monthly basis.
- Attendance at outside training schools or training courses provided by outside trainers should be encouraged to the extent possible within budget constraints.
- Informal group study sessions among the operators during shift hours should be encouraged to promote discussion and interest in the operation of the wastewater plant.
- Within budget constraints, operators should participate in correspondence course training offered by California State University at Sacramento.

As an additional aspect of the training program, the wastewater operators should have access to various periodicals pertaining to wastewater treatment. Among the recommended periodicals are:

- *Operations Forum*, a publication of the Professional Wastewater Operations Division of the Water Environment Federation.
- *Water Environment and Technology*.

## 1.5 PERMITS

The Shaw AFB WWTP is designed to be in compliance with the National Pollutant Discharge Elimination System (NPDES) Permit (SC 0024970). The Shaw AFB WWTP discharges to Beech Creek Tributary which discharges to the Wateree River. The NPDES permit discharge permit limitations are presented in Table 1.1.

In addition to the criteria presented in Table 1.1, general operating requirements which should be followed are summarized below.

1. The plant should have a continuous recording flow monitoring system capable of measuring and recording the total and maximum daily flow. The calibration and accuracy of the plant flow meter must be maintained such that flows are measured with a deviation of less than 10 percent from the true discharge rate throughout the expected range of flows.
2. Monitoring results obtained each month shall be reported monthly on a Discharge Monitoring Report Form to the South Carolina Department of Health and Environmental Control (DHEC). The reports must be submitted no later than the 28th day of the following month.
3. Test procedures for the analysis of pollutants shall conform to the State Environmental Laboratory Certification Regulations and 40 CFR Part 136 Chapter 1, Subchapter D.
4. Records of monitoring data shall be maintained including the date, exact place, and time of sampling or measurement, the initials of the person performing the measurement, the dates and times the analyses were performed, a reference to the written procedure used, and the raw data and final results of the analyses.
5. If monitoring of any pollutant is performed more frequently than required by the permit using approved analytical methods, the results shall be included in the calculations and reporting on the Discharge Monitoring Reports.
6. All records and information collected from the monitoring activities required by the permit, including all records of analysis, calibration, and maintenance of instruments and flow meters, shall be retained for 3 years.

**TABLE 1.1**  
**Shaw AFB WWTP**  
**NPDES Permit Limitations**

Parameter	Units	30-Day Average	Daily Maximum	Daily Minimum
Flow	MGD	1.2	Monitor only	--
Biochemical Oxygen Demand (5-day)	mg/l	15	30	--
Suspended Solids	mg/l	30	60	--
Ammonia ( $\text{NH}_3\text{-N}$ ) (Mar-Oct)	mg/l	--	4.0	--
Dissolved Oxygen	mg/l	--	--	6.0
Total Residual Chlorine (TRC)	$\mu\text{g/l}$	--	100	--
Total Phenols	mg/l	Monitor Only	--	--
Fecal Coliform	Colonies/100 ml	1,000	2,000	--
pH	Standard Units	--	8.5	6.0

7. Noncompliance with provisions and limitations in the permit which may endanger public health or the environment must be reported to DHEC verbally within 24 hours and in writing within 5 days of becoming aware of such conditions. The report should include a description of the discharge and cause of noncompliance and the period of noncompliance including exact dates and times. Noncompliance of a nature not considered to be a danger to public health or the environment should be reported in a narrative form at the time of submittal of the Discharge Monitoring Report.
8. The WWTP shall at all times be properly operated and maintained, including all systems installed to achieve compliance with the permit. Proper operation and maintenance include effective performance in accordance with design criteria, adequate operator staffing and training, and adequate laboratory and process controls.
9. An operator shall be provided who has a grade equal to or higher (as certified by the South Carolina Board of Certification for Environmental Systems Operators) than the classification designated for the plant. For the Shaw AFB, a minimum Class B operator is required.

## **1.6 SLUDGE LAND APPLICATION PERMIT**

The Shaw AFB WWTP has a Land Application Permit, State Land Application Permit #ND0070173, to apply digested, stabilized sludge to a 171-acre tract of forested land on the base. The permit contains requirements for monitoring of sludge, soil, and groundwater wells. The permit also contains operation and reporting requirements. Shaw AFB must comply with all conditions of this permit. Any noncompliance constitutes a violation and is grounds for enforcement action by the state of South Carolina.

Concentration limits for each pollutant found in the sewage sludge is set in Chapter I of Title 40 of the Code of Federal Regulations, Part 503.13. These limits are presented in Table 1.2

**TABLE 1.2**  
**Shaw AFB WWTP**  
**Ceiling Concentrations**

Pollutant	Ceiling Concentration (milligrams per kilogram)*
Arsenic	75
Cadmium	85
Chromium	3000
Copper	4300
Lead	840
Mercury	57
Molybdenum	75
Nickel	420
Selenium	100
Zinc	7500

\* Dry weight basis

## 1.7 PERSONNEL REQUIREMENTS

### 1.7.1 Certification Requirements

The Shaw AFB WWTP is an activated sludge wastewater treatment plant within the State of South Carolina and, as such, must comply with the rules of DHEC and the South Carolina Environmental Certification Board. DHEC, in the NPDES permit issued to Shaw AFB, has classified the WWTP as a Class IIIB plant. A class IIIB plant is required to have a Class B domestic plant operator in charge. The WWTP meets this requirement. Mr. Grooms, the Utilities Operations Supervisor, possesses a Class A domestic certificate. The requirements for obtaining a Class B certificate are as follows:

- Hold a valid "C" certificate in wastewater treatment.
- Successfully complete a "B" level examination.
- Have a minimum of three years of actual operating experience as an operator of a wastewater treatment plant.

Each certificate issued by the Board of Certification must be renewed annually on or before June 30th. Each applicant applying for renewal of a wastewater treatment certificate must, in every 2-year period, provide evidence of having completed 12 hours of relevant continuing education. In lieu of continuing education, the applicant may take and pass the appropriate examination for his/her certificate of a higher grade.

### 1.7.2 Manpower Requirements

The Shaw AFB WWTP is staffed by one Non-Commissioned Officer In Charge (NCOIC), one utility supervisor, four civilian plant operators, one maintenance mechanic, seven military operations specialists, and one laboratory technician. The overall management of the wastewater treatment plant is directed by the Infrastructure Superintendent, and above that position is the Chief of the Operations Branch of Civil Engineering. In addition to the wastewater treatment plant and laboratory, the O&M personnel are responsible for twelve lift stations, six water booster stations that contain lime, fluoride, and chloride feeders, and three swimming pools. Civilian operators spend approximately 60-65 percent of their time on activities related directly to the wastewater treatment plant or laboratory due to their other responsibilities. The maintenance mechanic is approximately 50 percent available for plant maintenance. The military operator has approximately 75 percent utilization on utilities O&M, of which 65 percent

is available for WWTP plant activities. The Infrastructure Superintendent, sanitation supervisor, and NCOIC are approximately 50 percent available for plant O&M supervision after taking into consideration their off-plant responsibilities. This results in an approximate available manpower of eight full-time persons for the wastewater treatment plant. The plant should be staffed 24 hours per day.

## CHAPTER 2

### DESCRIPTION OF FACILITY

#### 2.1 INTRODUCTION

The purpose of this chapter is to provide a thorough description of the processes and equipment at the Shaw AFB wastewater treatment plant. This description is designed to present a general understanding of the systems involved in the plant, how they function, and how they are interrelated. Some numbers regarding the equipment sizes and capacities are included when necessary.

##### 2.1.1 General

The Shaw AFB wastewater treatment plant consists of a biological treatment system employing the activated sludge process and tertiary filtration. The plant utilizes preliminary and secondary and tertiary treatment processes. Sludge stabilization and dewatering processes are also provided. A flow schematic of the Shaw AFB WWTP was provided in Figure 1.1.

## 2.2 COLLECTION SYSTEM AND LIFT STATIONS

The Shaw AFB wastewater treatment plant is located in the southwest quadrant of the base. Flow to the WWTP is through force mains and a series of lift stations located throughout the base. The major sources of wastewater flow to the WWTP are:

- Base housing area
- Maintenance shops
- Flightline area
- Administrative buildings

Nondomestic wastewater from maintenance shops are normally pretreated to remove floating oils prior to their discharge to the domestic sewer. There are twelve (12) remote lift stations located throughout the base. The lift stations are located as follows:

- Station No. 0012 Shaw Drive Pumping Station
- Station No. 0116 Aero Club Lift Station
- Station No. T-28 Mobile Communications Bldg. Lift Station
- Station No. 600 Main Lift Station
- Station No. 600 Old Main Lift Station
- Station No. 1130 9th Air Force Lift Station
- Station No. HQ Headquarters
- Station No. 1216 Aircraft Maintenance Lift Station
- Station No. 1600 AGE Maintenance Lift Station
- Station No. 3227 Old Wherry Housing Area Lift Station
- Station No. 5630 New Wherry Housing Area Lift Station
- Station No. 0306 WWTP Influent Pump Station

## **2.3 PRELIMINARY TREATMENT**

The preliminary treatment processes employed at the Shaw AFB WWTP are comminution, flow measurement, grit removal, manual screening, and influent pumping.

### **2.3.1 Plant Headworks**

Raw wastewater is pumped from Lift Station 600 and enters the treatment plant through a 14-inch pipe. This lift station is equipped with a macerator and a manual bar screen. There is an emergency power generator located at this lift station. Old pump station 600 serves as a backup and does not operate under normal conditions.

### **2.3.2 Grit Chamber**

Influent flow enters the new grit chamber structure and flows through the aerated grit chamber. The chamber is 23 feet long by 4.5 feet wide and has a water depth of 5.5 feet for a total volume of 4,250 gallons. At design flow the hydraulic retention time in the grit chamber is approximately five minutes. The grit chamber is equipped with two blowers and air diffusers for supplying air. Grit is removed from the bottom of the chamber by a motorized collector with buckets mounted on a drive chain. The buckets pull grit toward a collection sump at the influent end of the chamber. The grit is picked up from the sump by the grit screw conveyer and deposited in the grit dumpster.

### **2.3.3 Equalization Basin**

Pretreated influent wastewater flows to the plant equalization basin. The equalization basin dampens flow and concentration spikes to the treatment plant by providing an in-line reservoir of wastewater. The equalization basin is 54 feet by 54 feet and 16.5 feet deep with an approximate volume of 350,000 gallons. The basin volume is capable of holding approximately 8 hours of average daily flow. The equalization basin is equipped with two 388 cubic-feet-per-minute centrifugal blowers for aerating and mixing the influent wastewater through a grid piping and diffuser system. This basin is designed for dampening hydraulic peaks during high flow periods or for containing and equalizing contaminant spikes.

### **2.3.4 Influent Pump Station**

Adjacent to the equalization basin is the new screw lift pump station and wet well. Wastewater from the equalization basin flows to a flow distribution box which contains two 18-inch sluice gates. These gates control flow to the suctions side of the screw

pumps. An 18-inch invert and two channel sluice gates allow wastewater to flow to the suction side of the screw pumps. The two 1425-gpm capacity screw pumps lift the influent wastewater to a channel and gravity line that flows to the aeration basin splitter box. The motor controls for the screw pumps are equipped with variable speed drives to vary the speed of the screw pumps.

At the upper elevation of the screw lift pumps, flow is discharged into an open channel. Lime is added to the waste stream at this location to ensure that the activated sludge process has sufficient alkalinity for nitrification and to ensure that effluent pH is not reduced below permit limitation.

## 2.4 AERATION BASINS

The WWTP is provided with three aeration basins for the biological treatment of organic wastes. The pretreated and equalized influent flows to the aeration basin splitter box where it is mixed with the return activated sludge before entering the aeration basins. The combined aeration basin volume is approximately 1.0 million gallons (MG). Aeration Basins Nos. 1 and 2 are rectangular basins, each having a volume of 377,000, and Aeration Basin No. 3 is a circular basin and has a volume of 246,000 gallons. The aeration basins are equipped with surface mechanical aerators. The rectangular basins each contain two 25-horsepower surface mechanical aerators. Basin No. 3 contains one 30-horsepower surface mechanical aerator. The current loading rates to the system and principal design criteria are as follows:

<u>Current Loading</u>		<u>Principal Design Criteria</u>	
Volumetric Organic Loading Rate	11.9 lb BOD/1,000 ft <sup>3</sup>	Volume	1.0 MG
Hydraulic Retention Time	20 Hours	Hydraulic Detention time	2.0 hours
Food/Microorganism (F/M) Ratio	0.05 lb BOD/lb ML VSS	Loading	0.1 lbs BOD/lb MLSS
		LBS MLSS Under Aeration	23,000 - 34,000

The volumetric organic loading rate is in the lower end of the recommended range for extended aeration activated sludge systems (i.e., 10 to 25 lb BOD/1000 ft<sup>3</sup>). Similarly, the F/M ratio is in the lower end of the recommended range for extended aeration activated sludge plants (i.e., 0.05-0.15 lb BOD/lb ML VSS). The Hydraulic Retention Time is also on the lower end of the recommended range for extended aeration plants (18-36 hours). None of these loading factors are in a problem range as far as treatment efficiency or plant performance.

Control of DO in the basins is limited to two operational approaches. One is to raise or lower the liquid level in the basin thus decreasing or increasing the "bite" of the aerator blades in the mixed liquor. The other is to lower the mixed liquor concentration if sufficient DO cannot be imparted to the basin.

## 2.5 SECONDARY CLARIFIERS

Three circular secondary clarifiers are provided for the settling of biological sludge. The effluent of the aeration tanks flows to the in-plant pump station. Station 306 lifts the forward flow to the Flow Distribution Box. This structure splits the flow and distributes the mixed liquor to the secondary clarifiers for settling. The distribution structure consists of an elevated rectangular concrete box and three outlet chambers which discharge flow into the inlet pipes for the clarifiers. The clarifiers are 35 feet in diameter and have a side wide depth (SWD) of 8.5 feet. A collection trough around the perimeter of each clarifier receives effluent which flows to the tertiary filters. The return sludge flow is controlled by three telescopic valves, one per clarifier. The underflow rate for each clarifier is increased or decreased by manually lowering or raising the telescopic valves. Return sludge gravity flows from the telescopic valves to the aeration basins. Waste sludge gravity flows to the WAS pump station wet well and is pumped to the aerobic digesters via the WAS pumps. WAS flow rates are estimated using the rise in level inside the digester being utilized. A flow meter is to be installed on the WAS line to optimize sludge wasting and process control of the activated sludge system.

Current available surface area for the three units combined is 2,886 ft<sup>2</sup>. Current available volume is 183,600 gallons. Operating parameters for the secondary clarifiers under average flow conditions of 1.20 MGD and principal design criteria are as follows:

<u>Current Loading</u>		<u>Principal Design Criteria</u>	
Surface Loading rate	416 gpd/ft <sup>2</sup>	Design Hydraulic Loading	415 gpd/ft <sup>2</sup>
Solids Loading Rate	13.2 lb TSS/ft <sup>2</sup> -d	Weir Overflow Rate	3639 gpd/ft
Hydraulic Retention Time	3.7 hours		

## 2.6 TERTIARY FILTERS

Secondary clarifier effluent gravity flows to the tertiary filters. Flow enters the filters through a 16-inch cast iron pipe into the forebays and across the filter surface. The filters are multi-media units with a total filter bed depth of 3.67 feet. The top layers of filter media, 24 inches of anthracite is on top of 8 inches of sand followed by 12 inches of graded gravel. The media rests on a precast filter bottom. Filter effluent is collected in the filter bottoms and flows out of the filters through a 16-inch line to the chlorine contact chamber. Entering the filter bottoms is a 14-inch backwash line. During filter backwashing, this line is fed from a 2500-gpm backwash pump which uses the old chlorine contact chamber contents for washwater. Backwash waste exits the filters via the wash troughs and is routed by a 16-inch pipe to the backwash holding tank. From the backwash holding tank it is pumped to the equalization basin. The system is equipped with a surface wash system consisting of a 115-gpm surface wash pump and surface agitators fed by a 3-inch surface wash line. The automatic control function for this system has been bypassed and the system is presently manually operated. Differential pressure across the filters is measured by pressure gauges.

Backwash water for these filters is supplied from the old chlorine contact chamber.

## 2.7 CHLORINE CONTACT CHAMBER

The WWTP is equipped with two chlorine contact chambers. The old contact chamber is 60 feet by 20 feet and has a working depth of 6.5 feet for a total capacity of 58,000 gallons. The hydraulic detention time is approximately 1.4 hours at current average flow rates. One baffle wall directs the flow in a side-to-side pattern in the chamber. At the current average flow of 1.2 MGD, this basin has a more than adequate hydraulic retention time. At the influent end of the basin, the backwash water pump and the surface wash pump are mounted and their suction pipes extend into the basin. A PVC chlorine diffuser pipe extends into the contact basin approximately 20 feet from the influent end of the chamber.

The old chlorine contact chamber also contains two air diffusers near the effluent end of the tank for the purpose of adding dissolved oxygen to the plant effluent. The diffusers are supplied by an air blower in the filter control building. The blower has a capacity of 250 cfm. Also at the effluent end of the old chlorine contact chamber is a sulfur dioxide diffuser. Sulfur dioxide is added to the chamber just prior to the flow entering the outlet weir box of the chamber. Treated effluent flows out of the chamber through the outlet weir box to the effluent Parshall flume and through the effluent sewer to the plant outfall.

The new chlorine contact chamber is 75.5 feet in length by 11 feet wide by 8 feet of operating depth for a total capacity of approximately 50,000 gallons. At current average daily flow rates, the hydraulic retention time is approximately 1 hour. The chamber is equipped with a chlorine diffuser at the influent end of the tank and a sulfur dioxide diffuser at the effluent end of the tank. The new chlorine contact chamber was installed to serve as a backup tank to be utilized when it becomes necessary to bypass the tertiary filters.

Chlorine gas is fed through a 200-pound-per-day, wall-mounted chlorinator from 150-pound chlorine bottles. The chlorinator is located in the old laboratory building. Sulfur dioxide is fed by two 50-pound-per-day gas feeders. An average of 40 to 50 pounds per day of chlorine gas and sulfur dioxide is being fed to disinfect and dechlorinate the effluent and is resulting in an average maximum chlorine residual in the effluent of 210 µg/L.

Chlorine gas and sulfur dioxide feed control are manual. Data are provided by plant effluent samples which are analyzed for total chlorine residual. These data are used to make adjustment in the chlorine and sulfur dioxide feed rates.

## 2.8 AEROBIC DIGESTERS

The Shaw AFB WWTP is equipped with three aerobic digesters. Each unit has a surface area of 490 ft<sup>2</sup> and a 18-ft SWD for a unit volume of approximately 65,000 gallons. The total volume of the three units is 195,000 gallons. Diffused air is provided to maintain aerobic conditions and mixing level requirements by positive displacement blowers. Two of the digesters were part of the plant prior to the recent upgrade, and the third unit is new. The old digesters' blowers are located in the blower room on the lower level between those units. There are two 250-cfm units. The two new digester blowers are adjacent to the new digester mounted on an outside slab. These units are 240-cfm positive displacement blowers. Air is delivered by piping and 12-inch static tube aerators arranged in a grid on the bottom of the digesters. Each digester is equipped with 12 aerators. Each digester is also equipped with a new decanting weir for drawing supernatant. The decanting weir can be lowered on a worm gear to the level of the supernatant. Average waste sludge concentration is approximately 7,500 mg/L. The current loading factor is approximately 0.019 lb TSS/ft<sup>3</sup>-d. This loading level is below the design range for aerobic digesters (i.e., 0.024-0.14 lb solids/ft<sup>3</sup>-d).

## 2.9 SLUDGE DRYING BEDS

There are a total of seven (7) sludge drying beds. Each of the four large drying beds is 65 feet long and 20 feet wide. The three smaller beds are each 50 feet long and 20 feet wide. Up to 12 inches of sludge can be pumped onto each bed.

Digested sludge can be drawn to the drying beds from the digesters by gravity flow depending on the level of sludge in the digester. Alternatively, sludge can be pumped into the drying beds from the digesters by the new digested sludge pump station. Water from these drying beds flows through underdrains to the wastewater holding tanks and is then pumped to the equalization basin.

## 2.10 DIGESTED SLUDGE/LIME CONDITIONING SYSTEM

The digested sludge is pumped from the aerobic digesters into the lime stabilization system. The digested sludge pump station consists of two 130-gpm peristaltic pumps and associated piping and valving.

The lime stabilization system has two 25,000-gallon underground reaction/stabilization vessels. The sludge and lime are mixed and aerated in these vessels. Two 160-cfm positive displacement blowers with air supply lines and static tube aerators provide the air. One 250-gpm lime stabilization sludge pump is used for pumping out the stabilized sludge from the reaction vessels.

The lime stabilization feed system also has one 12-foot diameter by 36-foot high lime storage silo, a 2.5-cubic foot hopper to receive lime from the silo and transfer it to the feed equipment, a 1.5-horsepower vibratory motor and a 100-cubic-feet-per-hour maximum volumetric feeder.

The system is currently operated so that digested sludge is conditioned with lime to a pH of 12.0 and held in the vessels for a minimum of 2 hours at that pH.

## **2.11 LAND APPLICATION SYSTEM**

Stabilized sludge is hauled by tank truck to the 171-acre land application site. The site is located between the flight line and the east boundary of the base. The site is in a planted pine forest. Rows have been cleared between the trees for the tank truck to pass through the site as the sludge is surface-applied. The WWTP has two options for hauling sludge to the site. The Base owns a 2,000-gallon tank truck which is equipped for surface application of sludge. The other option is to use a contractor whom the base has hired under an open-ended, as-needed purchase order. Sludge drying beds are available to ensure that there is sludge disposal capability available at the plant when needed.

## CHAPTER 3

### THEORY OF OPERATION OF UNIT PROCESSES

#### 3.1 PRELIMINARY TREATMENT

##### 3.1.1 Introduction

Incoming wastewater to a treatment plant contains a very diverse blend of constituents. Coarse materials such as string, rags, paper, cans, and wood can enter a plant through the sewer system. Wastewater also contains a relatively large amount of inorganic solids such as sand, gravel, and cinders which are collectively called grit. Besides being unaffected by biological treatment, materials such as the above can damage pumps and other equipment as well as plug pipelines. Removal of these materials helps to prevent disruption of downstream processes and to protect equipment. The Shaw AFB WWTP contains several preliminary treatment processes designed to remove these materials.

##### 3.1.2 Screening

Screening was one of the first methods used to remove large solids from wastewater. The main purpose of many of the first wastewater plants was to only remove the visible, large solids. Coarse screens are normally employed as the first treatment unit for the primary purpose of protecting plant equipment from physical damage or reduced operating efficiency. A manual bar screen is located at Lift Station 600 in the Shaw AFB WWTP.

##### 3.1.3 Grinders and Macerators

Grinders and macerators are used to reduce the particle size of screenings to a size that will not clog pumps. They are frequently incorporated in facilities to eliminate the need for storing and separately disposing of screenings or to supplement the screening process. For this reason, they tend to reduce odors and unsightliness on the plant site. Comminutors and grinders do have several drawbacks. Among these are rag accumulations on downstream equipment and the tendency to create "ropes" of the material it has ground up. Three grinder pumps and a macerator are located at Lift Station 600 in the Shaw AFB WWTP.

### **3.1.4 Grit Removal**

The function of grit chambers is to remove large inorganic solids such as sand, gravel, or cinders. They are designed to remove solid materials that have subsiding velocities or specific gravities substantially greater than those of the organic solids in wastewater. Most grit chambers are constructed to capture particles with a specific gravity greater than 2.65 and a diameter larger than 0.02 centimeters.

The objective of grit removal is to remove the inorganics from the wastewater flow with a minimum of organic materials also being removed. If flow rate through a grit chamber is too high, little inorganic material will settle out. If flow rate is too low, a large amount of organic matter will settle out with the grit. Excessive organic matter in the grit leads to more frequent cleaning of the grit chambers and can lead to odor problems while the grit is stored awaiting disposal. The grit chamber at the Shaw AFB is at the inlet of the WWTP.

### **3.1.5 Grit Collection**

Accumulation of settled grit at the bottom of grit chambers must be removed regularly. If cleaning is ignored, the efficiency of the unit will decline and cause unwanted material to pass into the plant. At the Shaw WWTP, grit settles in a horizontal grit chamber, is raked by a rotating mechanism to a sump, and is then removed by a screw conveyor.

### **3.1.6 Grit Disposal**

The different methods of grit disposal include sanitary landfills, lagoons, and land spreading. In general, it is best to bury and cover the grit, as the residual organic content can still be a nuisance. Since grit has good structural stability, it will not cause problems with future use of the land. The grit may be combined with other waste solids from the treatment plant before disposal. The Shaw AFB WWTP grit is currently deposited in a dumpster and hauled to a disposal site.

## 3.2 BIOLOGICAL TREATMENT PROCESS

### 3.2.1 Introduction

Biological treatment is the most important step in processing domestic wastewater. Physical treatment of wastewater by sedimentation only removes about 35 percent of the biochemical oxygen demand (BOD) due to a high percentage of nonsettleable organic solids (colloidal and dissolved) in domestic wastes. Chemical treatment alone is not favored because of high costs. A modern treatment plant uses a variety of physical, chemical, and biological processes to provide the best, most economical treatment.

Biological treatment systems are "living" systems which rely on mixed biological cultures to break down waste organics and remove organic matter from solution. Domestic wastewater supplies the biological food and growth nutrients. A treatment unit provides a controlled environment for the desired biological process.

Wastewater treatment operations contain communities of microorganisms made up of populations of individual species. Within the community, changes can occur in populations present as the system responds to changes in the quantity and character of the material entering in the feed stream or to changes in the physical environment. If the nature of the waste being treated is such that it supports a broad and diverse microbial community, the community will adapt readily to changing environmental conditions, and the system will appear fairly stable from the microscopic point of view. Under some circumstances, the community may be restricted. This leads to an unstable biochemical environment and a process which is difficult to control. Generally, complex integrated communities with a large number of diverse species are considered to be healthy ecosystems.

### 3.2.2 Microorganisms in Biological Systems

#### 3.2.2.1 Bacteria

Bacteria are the simplest forms of plant life which can use soluble food and are capable of self-reproduction. Bacteria are single-celled, independent organisms with each cell capable of carrying out all necessary functions of life. Bacteria are fundamental microorganisms in the stabilization of organic wastes and therefore of basic importance in biological treatment. Uncontrolled, bacterial decomposition of organic wastes can produce odors and objectionable conditions. In controlled environments, bacteria can stabilize organic matter and prevent objectionable conditions.

Based on nutrient requirements, bacteria are classified as heterotrophic or autotrophic, although several species may function both heterotrophically and autotrophically.

Heterotrophic bacteria use organic compounds as an energy and carbon source for synthesis. A term commonly used instead of heterotroph is saprophyte, which refers to an organism that lives on dead or decaying organic matter. The heterotrophic bacteria are grouped into three classifications depending on their action towards free oxygen. Aerobes require free dissolved oxygen to live and multiply. Anaerobes oxidize matter in the complete absence of dissolved oxygen. Facultative bacteria are a class of bacteria which use free dissolved oxygen when available but can also respire and multiply in its absence.

Autotrophic bacteria use carbon dioxide as a carbon source and use inorganic compounds for energy. Autotrophs of greatest significance in wastewater treatment are the denitrifying and sulfur bacteria.

Bacteria are also classified according to the temperatures at which they thrive. The largest proportion of saprophytes thrive at 20° to 40°C or 68° to 104°F and are called mesophilic types. Variations from this temperature range limit the activity of mesophilic bacteria, practically eliminating them at high and low temperatures. Other bacteria thrive at higher temperatures, in the range of 55° to 66°C or 130° to 140°F. These are known as thermophilic types. Very few types find their optimum temperatures at low temperatures (0° to 5°C or 32° to 40°F). These are known as psychrophilic bacteria. Mesophilic bacteria are important in all biological treatment systems. Thermophilic bacteria are important in some sludge digestion systems.

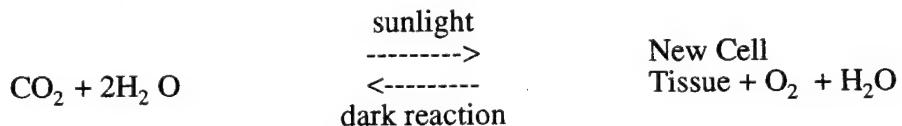
Bacteria have the ability to reproduce rapidly when in intimate contact with their nutrient material (i.e., wastes) and feed readily by taking in food directly through their cell walls. Bacteria occur in three basic shapes: rods (bacilli), spheres (cocci), and spirals. While all these forms are found in wastewater, quite often they are found individually enmeshed or associated in masses, slimes, or flocs. They are capable of growth in suspended or attached masses.

### 3.2.2.2 Fungi

Fungi are heterotrophic microorganisms which are predominantly filamentous (stringy) in nature and quite different in shape from the bacteria. Fungi are multicellular as opposed to the single-celled bacteria. Generally, fungi are somewhat larger than the bacteria and do not have a primary role in wastewater treatment. At times, certain fungi can cause serious interferences or nuisance problems in wastewater treatment, especially in settling. This generally occurs in low pH or low nitrogen environments.

### 3.2.2.3 Algae

Algae are microscopic autotrophic-photosynthetic plants. The process of photosynthesis is illustrated by the equation:



Energy for photosynthesis is derived from sunlight. Photosynthetic pigments biochemically convert the energy in the sun's rays to useful energy for plant synthesis. The most common pigment is chlorophyll, which is green in color. Other pigments or combinations of pigments result in algae of a variety of colors, such as blue-green, yellowish green, brown, and red. In the prolonged absence of sunlight, the algae perform a dark reaction--for practical purposes the reverse of photosynthesis. In the dark reaction, the algae degrade stored food and their own protoplasm for energy to perform essential biochemical reactions for survival. The rate of this endogenous reaction is significantly slower than photosynthetic reaction.

There are a variety of algae forms that may be found. Raw wastewaters, unless exposed to sunlight, do not usually contain algae, while trickling filters and oxidation ponds have large numbers of algae in areas exposed to sunlight. Algae frequently play an important role in providing oxygen to stabilization ponds through photosynthesis. Because algae grow rapidly as a result of excess amounts of nutrient nitrogen and phosphorous (especially the latter), their excessive growth can be a source of nuisance problems in streams, lakes, ponds or other bodies of water. The most serious algae problems in receiving waters are associated with the growth of blue-green algae. Trickling filters, final settling tanks, discharge channels, and receiving streams will

frequently have filamentous, attached green algae or brown diatoms at different times of the year.

### 3.2.2.4 Protozoa and Higher Animals

Protozoa are single-celled animals that reproduce by binary fission. The protozoa of significance in biological treatment systems are strict aerobes found in activated sludge systems, trickling filters plants, and oxidation ponds. These microscopic animals have complex digestive systems and use solid organic matter as an energy and carbon source. Protozoa are a vital link in the aquatic food chain since they ingest bacteria and algae and are scavengers and predators in biological treatment processes.

A number of types of protozoa are common to biological processes such as activated sludge. Protozoa with cilia may be categorized as free-swimming and stalked. Free-swimming forms move rapidly in the water ingesting organic matter at a very high rate. The stalked forms attach by a stalk to particles of matter and use cilia to propel their head about and bring in food. Another group of protozoa move by flagella. Long hair-like strands (flagella) move with a whip-like action providing mobility. Amoeba move and ingest food through the action of a mobile protoplasm.

Rotifers are the simplest multicelled animals. They are strict aerobes and metabolize solid food. A typical rotifer uses the cilia around its head for catching food. The name rotifer is derived from the apparent rotating motion of the cilia on its head. Rotifers are indicators of low pollutational waters and are regularly found in streams and lakes.

### 3.2.3 Bacterial Utilization of Food

As stated earlier, bacteria in biological wastewater systems utilize the incoming waste for food. Bacteria can only use organic wastes which are in a soluble, or dissolved, state. Soluble organics are ingested directly through the cell wall and membrane by the bacteria for utilization. This process is known as absorption, or the taking up of one substance into the body of another.

For insoluble organics or particles too large to be directly absorbed, the process is more complicated. First, the waste particle is adsorbed by the bacteria. This is a process of adherence where the waste particle becomes attached to the cell wall of the bacteria. The bacteria will then begin to secrete enzymes which act to break down the specific organic. As the organic is broken down, it is then taken into the cell, or absorbed.

The utilization of organic waste as food by bacteria is an accumulative process. Initially, when a complex organic is introduced into a biological system, one type of bacteria attacks one part of the organic material and other bacteria attack the remaining parts. The bacteria digest that portion of the organics they have absorbed through their cell walls and produce certain waste products. These waste products are then used as a food source by other microorganisms which, in turn, produce waste products that are subsequently used as food by yet other microorganisms. This accumulative process continues until the original complex organic is completely broken down and assimilated by the biological population.

### 3.2.4 Factors Affecting Growth

Several factors affect the growth of microorganisms. These include the following:

1. pH. An environmental factor which influences the growth rate and limits the growth in any biological system is the hydrogen ion concentration, i.e., the acidity or alkalinity of the liquid environment of the process. This is most conveniently expressed as the pH of the system.

Each species of microorganism is limited by a range of pH values within which growth is possible. The optimum pH value for any species is that at which the growth rate is most rapid. Often this pH range is surprisingly broad. Most bacteria and protozoa have pH optima near 7 but thrive in a range of 5 to 8.

In biological populations found in waste treatment plants there are a series of individual species of microorganisms acting and interacting at the same time. Within this community, species changes can occur as the system responds to changes in the type or quantity of the organic material entering the influent stream. The activities of the species as they feed upon the organic matter and grow result in the formation of acidic or alkaline products. As these products are released from the cell, an increase or decrease in the system pH may occur.

Each biological system can accept flows within a pH range without upsetting the system or changing the internal system pH. In some systems this range is narrow, but some systems have been known to accept flows with pH variation of 5 to 11 without noticeable effects. pH changes of long duration above or below the acceptable range a system can tolerate are considered toxic. Wide

fluctuations in pH for short periods of time can usually be tolerated by a healthy system.

2. Nutrients. All living cells require a number of basic nutrients for survival. Generally, the two most important for biological systems are nitrogen and phosphorous. These nutrients must exist in certain proportions to maintain a healthy population of microorganisms in the system. Both nitrogen and phosphorous are necessary to maintain cell respiration and reproduction. Nitrogen is needed for generating new cell material, while phosphorus is essential to enzyme production. If the amount of these nutrients added is not sufficient, the formation of unwanted types of microorganisms is likely to occur.

Generally, a good rule of thumb for nutrient balance in the incoming wastewater to a biological treatment system is that for each 100 parts of raw  $BOD_5$ , there should be about 5 parts of total nitrogen and 1 part of total phosphorus.

3. Temperature. In order to function at maximum efficiency, bacteria require a favorable temperature. They are very susceptible to changes in temperature in that their rate of growth and reproduction is definitely affected by such variations.

As stated earlier, the larger portion of these bacteria thrive best at temperatures from  $20^{\circ}\text{C}$  to  $40^{\circ}\text{C}$  or  $68^{\circ}\text{F}$  to  $104^{\circ}\text{F}$ . These are known as "mesophylic" types. Variations from this temperature range limit the activities of mesophylic bacteria, practically eliminating it at extremely low temperatures and at high temperatures. Temperatures, consequently, are of major importance in the operation of a biological process.

The optimum temperature is that at which the growth is most rapid, and for most bacteria it is closer to the maximum than to the minimum temperature. Growth at the minimum temperature is typically quite slow. The rate increases exponentially, with increasing temperature reaching a maximum at the optimum temperature and falling abruptly to zero at a few degrees above the maximum. For most organisms, the growth rate increases twofold for each  $10^{\circ}\text{C}$  rise in temperature between the minimum and optimum.

Time is an important factor in considering the effects of temperature, particularly temperatures above the range of growth. Some effects of elevated

temperatures are reversible, and short exposure to an elevated temperature may not be lethal, although longer exposure at that same temperature would be. The higher the temperature, of course, the less time is required for killing and the greater is the probability that irreversible damage will occur.

When an organism is subjected to a temperature change within the biologically active range, the response of the organism at the new temperature depends on the ability to adapt or acclimate to the new environment. In areas with prominent seasons, the temperature changes from winter to summer or summer to winter can cause plant upsets, sometimes of a serious nature.

4. Oxygen Supply. In aerobic biological systems, an adequate oxygen supply is necessary for growth to occur. Oxygen can be introduced to the biological culture through various means depending on the type of systems. Some derive their oxygen supply from the microorganisms themselves, as in the case of algae in ponds. Ventilation, either natural or forced, is required in processes such as activated sludge.
5. Shock. A shock can be defined as any abrupt change in the feed to the system that may result in a process upset. A process shock can be classified as:
  - A qualitative shock - a change in the type of organic substances fed to the organisms;
  - A quantitative shock - a change in the total amount of organic substances fed to the system;
  - A hydraulic shock - a sudden change in flow rates;
  - Toxic shock - this includes such things as pH, temperature, conductivity, toxic materials, etc.

Of major concern in a plant is the degree of shock that can be tolerated at any one time without causing process upsets and permit violations. Important points for personnel to realize in handling shock loads are:

- Biological processes can handle shock loadings up to a certain degree.
- The degree of shock that can be tolerated by a plant depends upon the stability of the plant at that particular time. (Plants in the process of

recovering from one type of shock are less likely to be able to withstand another shock if this second shock occurs during this recovery period.)

- Complete effects of some shock loads are not immediately visible.
- Temporary rises in flow rates, organic loads, or chemical or physical changes (referred to as *spikes*) do not necessarily constitute shock loads. Equalization capabilities of the plant will dampen the effect of these "spikes" and they often will pass through the process with no adverse effects.

### **3.2.5 Equalization**

One of the most frequently encountered problems in wastewater treatment is process upsets related to highly variable contaminant levels or intermittent high flow rates. Such variability in wastewater composition and quantities can result from high rainfall or unauthorized dumping of material into the collection system. These fluctuations can be so severe that process upset and subsequent problems can occur before the system is able to compensate. For this reason, wastewater equalization often is implemented to control the extreme fluctuations in flow and contaminant concentrations. Whenever treatment process upsets do occur, proper operation of equalization should be one of the first operating conditions to be checked.

#### **3.2.5.1 Purpose of Wastewater Equalization**

Wastewater equalization can accomplish three basic tasks. The first is hydraulic or flow equalization which dampens flow surges to downstream treatment processes. Flow equalization can only be accomplished by placing some type of variable liquid volume storage tank in the wastewater flow path upstream of sensitive process equipment. The liquid is stored in the variable volume tank during high flow periods and then is released during low flow periods. Therefore, the flow equalization capability is directly related to the usable variable volume of the tank.

The second equalization task is concentration equalization. Concentration equalization is accomplished by mixing low and high contaminant concentration wastewater, which results in concentrations close to the average and reduces downstream concentration fluctuations. As with flow equalization, some type of storage must be provided which stores highly (or slightly) contaminated flow until such time as the contaminant concentration cycles to the other extreme. Contaminant equalization can be

accomplished by placing in the flow path a storage tank and mixer with sufficient volume to mix the low and high concentration wastes.

The third equalization task, an offshoot of the earlier discussed two, is to allow means to control the contaminant mass loading to the downstream treatment process(es) to within limits set by the operator. This is accomplished by increasing or decreasing flows to the process from the equalization basin. The operator would have the option of lowering flow during periods of high concentrations and raising flows during periods of low concentrations and could control the load to the process to desired levels. This system requires some analytical work and requires an equalization tank large enough to allow the operator to vary the tank level. It has the advantage that it can reduce the possibility of shock loading and allows much finer control of the downstream treatment process(es).

### 3.2.5.2 Flow-Through Equalization

The system of flow-through equalization dampens and greatly reduces flow and concentration variations, but does not eliminate them. Typically, the system operates on a continuous basis and requires a large tank, a mixing system, and an effluent control device such as a weir, orifice, control valve, or variable rate pumping. For flow equalization, the tank must be designed to fluctuate in volume in response to influent flow rates. For contaminant equalization, the tank must be large enough to hold the volume which corresponds to the discharge cycle of high or low concentration wastes. The more cycles the tank can hold, the better the equalization achieved. The effluent control devices selected will depend on the objective of the equalization. Pumps or flow control valves are used for maximum flow equalization or for controlled equalization of contaminant mass loadings.

The major advantage of a flow-through equalization system is its simplicity of operation and the continuous nature of its discharge. Flow and contaminant concentration changes do occur, but very gradually. This gradual change usually provides downstream processes, such as pH adjustment, with adequate time to respond. The major disadvantage of the system is the large tank size generally required.

### 3.2.5.3 Operational Considerations

The objective of equalization is to limit fluctuations in wastewater flow and/or contaminant concentrations to levels that will not adversely affect downstream treatment processes.

#### A. Mixing.

Mixing is an integral part of all equalization techniques. Flow equalization requires mixing to keep suspended material in suspension. Without it, solids will accumulate in the storage tank, thereby reducing the effective volume of the tank. Contaminant equalization requires mixing to blend the low and the high strength wastes together. And in the case of sidestream or batch equalization processes, mixing is required to insure a constant known concentration so that flow may be sent forward to downstream treatment system at a rate which will not cause process upsets. Mixing can also help to maintain aerobic conditions in the equalization vessel, which can be important in reducing odors and gas production should the organics in the wastewater be readily degraded under anaerobic conditions. For all these reasons, proper orientation and maintenance of the equalization mixing systems is critical to optimizing the effectiveness of the process.

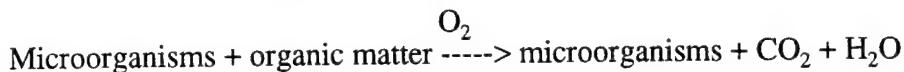
#### B. Routine Process Monitoring.

Equalization monitoring takes two forms. First, with the exception of a continuous flow-through system, the wastewater must be monitored for flow and/or contaminant concentration. Monitoring can be accomplished using either automated on-line equipment or by periodic measurements by the operator. The former is subject to breakdown and the latter is subject to slow response that may completely miss flow or contaminant surges.

### 3.2.6 Activated Sludge

One of the most common forms of biological treatment is the activated sludge process. Removal of organic matter from wastewater in the activated sludge process is accomplished by introducing the water to be treated into a tank containing a high concentration of actively growing microorganisms in the presence of dissolved oxygen. The microorganisms use the waste material as a source of food so as to obtain the energy necessary to grow and multiply. In so doing, the microorganisms convert the waste

materials into more stable end products such as CO<sub>2</sub>, water, and more microorganisms. The activated sludge process is illustrated by the basic reaction:



As the microorganisms grow and are mixed by the agitators in the aeration basins or reactor, the individual organisms clump together (flocculate) to form an active mass of organisms called "activated sludge." Wastewater flows into the aeration basins, where oxygen is injected and the activated sludge and the wastewater are thoroughly mixed. This mixture is called "mixed liquor."

Generally, the organisms in an activated sludge culture may be divided into four major classes: floc-forming organisms, saprophytes, predators, and nuisance organisms. These are not distinct groups; in fact, any particular organism may fit into more than one category at a time or may change groups as the selective pressures within the community change.

Floc-forming organisms play a very important role in the process, for without them the sludge could not be separated from the treated wastewater. Classification of organisms into the floc-forming group is complicated by the fact that protozoa and fungi can also cause bacteria to flocculate. Nevertheless, this group is primarily composed of bacteria. Flocculation is thought to be caused by natural polyelectrolytes, although their origin is uncertain.

The saprophytes are the organisms responsible for the degradation of organic matter. These are primarily bacteria and no doubt include most of the bacteria considered to be the floc formers. Nonflocculant bacteria are probably also present but are entrapped within the floc particles formed by the first group. The saprophytes can be subdivided into primary and secondary saprophytes, the primary ones being responsible for the degradation of the original substrates. No doubt the larger the number of substrates, the more diverse the community will be because of less competition for the same substrates. The secondary saprophytes feed upon the metabolic products of the primary ones.

The main predators in activated sludge communities are the protozoa which feed upon the bacteria. About 230 species have been reported to occur in activated sludge, and they may constitute as much as 5 percent of the mass of biological solids in the

system. Ciliates are usually the dominant protozoa both numerically and from biomass estimations. All but one of them are known to feed on bacteria, and the most important ones are either attached to or crawl over the surface of sludge flocs. On occasion, both amoebae and flagellates may be seen in small numbers, but they are not thought to play a major role in good settling, stable communities. It has been suggested that protozoa play a role in the formation of sludge flocs and contribute to the absence of dispersed bacteria in stable communities.

Nuisance organisms are those which interfere with the proper operation of the process when present in sufficient numbers. Most problems arise with respect to sludge settling and are the result of filamentous bacteria and fungi. If only a small percentage by weight of the community is made up of filamentous organisms, the effective specific gravity of the sludge flocs is reduced so much that the sludge is very difficult to separate by gravity settling. This leads to a situation known as bulking.

A properly operated activated sludge process will provide the conditions necessary to encourage the development of the beneficial organisms and to discourage growth of the nuisance organisms.

### **3.2.6.1 Steps in the Activated Sludge Process**

1. Mixing the Activated Sludge with The Incoming Waste. It is very important that the returned activated sludge (RAS) be thoroughly mixed with the incoming waste. The initial mixing is usually accomplished in one of the following ways.

In a conventional activated sludge process, the RAS and incoming waste are mixed at the inlet to the aeration tank. The agitation provided by the turbulence in the inlet pipes or channels usually provides the initial mixing.

In a complete mix activated sludge process, the RAS and the incoming waste are mixed in a line or channel and introduced to the aeration tank at various points throughout the length of the tank. Mixing occurs in the line as the liquid travels to its introduction point.

In a step aeration activated sludge process, the RAS is introduced at the inlet of the aeration tank. The incoming waste is introduced at several points along the length of the aeration tank. Initial mixing occurs within the aeration tank itself.

2. Aeration and Agitation of the Mixed Liquor. Aeration and agitation of the contents of the aeration basins are necessary to further mix the RAS with the incoming waste, keep the sludge in suspension, and supply oxygen required for biological oxidation.

The degree of mixing within an aeration system exerts a profound effect upon the degree of removal of organic compounds within these aeration basins. The microorganisms are limited in their ability to seek out their food, and mixing brings the organic matter into contact with these microorganisms. Good mixing also decreases the chances of localized differences of temperature or nutrient concentrations occurring within the aeration basin.

If mixing is too vigorous, it is possible that the floc particles that form within these aeration basins can be "sheared" or separated, and the settling ability of the sludge in the secondary clarifiers could be impaired. If mixing is not vigorous enough, settling of solids may occur in the aeration basin. Also, good contact between the organic matter and the microorganisms will not be accomplished.

Aeration and agitation of the mixed liquor are generally accomplished through one of two methods: subsurface diffused air or mechanical aeration. In a diffused air system, compressed air is introduced at the bottom of the tank. This causes the contents of the tank to be circulated by the air-lift effect. Two types of diffused air systems are usually found in aeration systems: coarse bubble and fine bubble. Fine bubble diffusers provide for more surface area for air-liquid contact, while large bubble diffusers generally present less operational problems such as clogging.

There are several types of mechanical aeration devices. Floating or fixed platform surface aerators are common. Most use blades to agitate the mixed liquor, and some utilize an updraft or downdraft pump or turbine. Also in use are submerged turbine aerators and horizontal rotating brush aerators. All these mechanical aeration devices serve to mix the liquid and entrain air bubbles in it.

The basic oxygen requirement is that there shall be sufficient oxygen added to the system to maintain at least 2 ppm of dissolved oxygen in all parts of the system under all loading conditions. The degree of treatment of the influent waste depends on how many microorganisms there are in the aeration system and how well these organisms work. In any activated sludge system, these

organisms require an aerobic environment, that is, the presence of dissolved oxygen. As the supply of food (organic matter) to the aeration system is increased, the microorganisms will increase their activities and will demand more oxygen. If the supply of oxygen does not keep pace with the demand, septic or anaerobic conditions may occur.

Extremely high oxygen residuals (9 ppm to 10 ppm) are not beneficial to the system and can sometimes lead to problems. Besides wasting oxygen, such high concentrations of dissolved oxygen can sometimes cause "bubbles" to be carried over into secondary clarifiers and hinder settling in these tanks.

3. Separation of Activated Sludge from the Mixed Liquor. Before the treated waste can be discharged into receiving waters, the activated sludge must first be removed. This is done in secondary or final sedimentation tanks called clarifiers. The cycle of sludge removal from these secondary clarifiers is much more important than with primary tanks. Some sludge is being removed continuously to be used as return sludge in the aeration tanks. This return sludge must be removed before it loses its activity because of the death of aerobic organisms resulting from the lack of oxygen at the bottom of the tank.

It is good practice to operate final clarifiers with a sludge inventory as small as possible. Minimizing sludge may be accomplished by removing solids at the same rate as they are applied. If solids output does not equal input, solids will accumulate in the final settling tank and will eventually spill over the effluent weir. As a result of solids accumulating in secondary clarifiers:

- Solids become thick and difficult to remove from the bottom;
- Portions of the sludge blanket could become anaerobic;
- MLSS concentration of the system will drop;
- Septic sludge gives off gases which could cause sludge to rise.

4. Return of Proper Amount of Activated Sludge. So that the biological solids do not accumulate in the secondary clarifiers, they must be removed at an average rate to that at which they are applied. It is necessary to return this sludge as rapidly as possible, with the least amount of water, to the head of the aeration basin. If the return rate is too slow, there will be insufficient bacteria in the

aeration tank to effectively reduce the organic material. If the rate is too high, settling characteristics of the sludge will be impaired.

5. Wasting of the Excess Activated Sludge. The objective of wasting activated sludge is to maintain a balance between the microorganisms and the amount of food such as total organic carbon (TOC) or chemical oxygen demand (COD). It is known that when the microorganisms remove organic matter from the wastewater, the amount of activated sludge increases. It has been estimated that under normal operating conditions about 1/3 of the usable organic matter is used for oxidation while the remaining 2/3 are used for synthesis. Large portions of the incoming waste are inert and not easily used. The result is that much of the substrate removed by the sludge remains in the floc and accumulates as either inert or living solids.

The objective of sludge wasting is to remove just that amount of microorganisms that grow in a period. When this is done, the amount of activated sludge formed by the microorganisms growth is just balanced by that which is removed from the process. This, therefore, allows the total amount of activated sludge in the process to remain somewhat constant.

This condition is called "steady-state," which is a desirable condition for operation. However, "steady state" can only be approximate because of the variations in the nature and quantity of the food supply and of the microorganism population.

Wasting of the activated sludge can be done on an intermittent or continuous basis. Intermittent wasting has one advantage in that less variation in sludge concentration will occur during the waste period and the amount of sludge wasted will be more accurately known. The disadvantages of intermittent wasting are that the sludge handling process may be overloaded and that the activated sludge process is out of balance for a period of time.

### **3.2.6.2 Activated Sludge Flow Models**

The two types of flow models referred to in activated sludge treatment are complete mix and plug flow.

1. Complete Mix Flow. In complete mix flow arrangements, the influent waste, mixed with the return sludge, is rapidly distributed throughout the basin, and

operating characteristics are identical throughout the basin. An important factor in complete mix flow patterns is that the process can handle surges in organic loading without adversely affecting effluent quality.

2. Plug or Series Flow. The plug flow arrangement is the oldest and most widely used form of reactor basin. One of the characteristics of the plug flow configuration is a very high organic loading in the inlet section of the basin. The loading is then reduced as the organic material in the raw wastewater is oxidized. As the complete mix configuration is noted for its ability to assimilate shock loads, plug flow reactors are able to avoid "bleed through," or the passage of untreated materials during peak flows.

### **3.2.6.3 Factors Affecting the Activated Sludge Process**

The factors previously discussed which affect biological processes (pH, temperature, nutrients, oxygen supply, and shock) all apply to the activated sludge process. In addition, several other factors must be considered.

1. Detention Time. It is commonly thought that the removal of organic matter in the activated sludge process takes place in two steps: the removal of organic matter from the wastewater by the sludge floc and the digestion of the organic material by the microorganisms in the floc.

The sludge floc is formed by mutual coagulation of bacteria with other suspended and colloidal matter. The floc gradually increases to a maximum size. The size depends on how much movement through the water the floc particles can stand without breaking apart (shearing). As the sludge floc moves through the aeration tank, it collides with the suspended and colloidal particles, which then adhere to or adsorb onto the floc. This process is called adsorption. As the floc travels through the basin it will also absorb soluble organic matter, allowing it to pass through the cell wall into the cell. This is called absorption. Adsorbed food matter must be broken into a simple soluble form before it can be absorbed into the cell. The adsorption process occurs very quickly in activated sludge treatment processes, usually requiring only 15 to 30 minutes to occur. But the process of absorption, converting this organic material to carbon dioxide, water, and more activated sludge, requires a longer period of time. As the microorganisms use the sorbed material the sorptive sites are reopened,

allowing more waste material to be trapped by the floc. The process of digesting this organic material must be completed before the organisms leave the aeration system. The aeration tank is sized to provide enough detention time to accomplish the treatment required.

2. Dissolved Oxygen Residual. As previously stated, all aerobic biological processes require an oxygen supply. Proper control of the activated sludge process requires that a residual of at least 2.0 mg/l of dissolved oxygen (DO) is maintained in the aeration basins at all times. Residuals below this point can cause shifts in the predominate species of organisms within the system and may encourage the growth of filaments. Maintaining a DO of 2.0 mg/l is recommended, not because the higher DO levels affect the process in any way, but only because it offers a degree of protection against large increases in organic loadings that may enter the process. Carrying too high a DO level can result in wasted energy (unnecessary cost). The upper limit of DO residuals should be in the range of 5 to 7 mg/l. The secret to control of dissolved oxygen in an aeration system is to carefully monitor all parameters as they enter the aeration system and adjust the DO as needed. As heavy organic loads arrive at the aeration system, the DO residuals should be monitored on an hourly basis as the change in organic loading takes place. DO residual tests should be run hourly until the change has been completed. As increases in organic loadings take place, it is only necessary to maintain DO levels above 2.0 mg/l at all times. Instantaneous drops in DO residuals to points slightly below 2.0 mg/l at the peak of a change are no cause for alarm. If the process DO residual recovers immediately (within 2 hours) and holds, no action is required. Consistent drops in DO residual below 1.0 mg/l in a 24 hour period can cause problems and corrective action must be taken.

#### **3.2.6.4 Operational Parameters**

There are a number of operating parameters important to the operation of activated sludge process. It must be noted that these operating parameters are provided for reference only. Each individual treatment system will have its own unique operating characteristics.

1. Mixed Liquor Suspended Solids (MLSS). This is a very important measurement and shows the amount of activated sludge inventory. It is recommended that the MLSS be determined on a daily basis.
2. Mixed Liquor Volatile Suspended Solids (MLVSS). This test indirectly shows the active biological fraction of mixed liquor solids and directly tells the amount of inert solids. For example, MLVSS will typically be 70 to 80 percent of the total MLSS. However, during times of heavy infiltration of the sewer system, the carryover of silt into the aeration basins may decrease the MLVSS to 55 to 60 percent. When the percent of MLVSS decreases, the total MLSS must be increased to maintain the same level of active organisms. It is recommended that the MLVSS be determined on a daily basis.
3. Food to Microorganism Ratio (F/M). This parameter is used to express the total loading of organics on the biological system. It is the ratio of pounds of BOD<sub>5</sub> entering the aeration basin per day to the pounds of MLVSS in the aeration basin and the secondary clarifier.

A high F/M reflects a high loading on the activated sludge system which will result in more waste activated sludge generated per pound of BOD removal. A very high F/M (above 0.5) indicates a more unstable system.

A low F/M (less than 0.1) at normal MLSS concentrations indicates a lightly loaded activated sludge plant. The waste sludge should be stable and may not require any added digestion.

F/M ratio is calculated as:

$$\frac{(\text{Aeration Influent BOD, mg/l})(\text{Influent Flow Rate, MGD})}{(\text{MLVSS Concentration, mg/l})(\text{Aeration Basin Volume, MGD})} \quad (8.34)$$

4. Sludge Age (MCRT, SRT) is the average length of time the activated sludge solids are in the system. Sludge age is an important parameter, because the amount of time that the microorganisms are given to breakdown the waste products has a significant effect on effluent quality. SA is calculated as:

$$(\text{MLVSS Concentration, mg/l})(\text{Aeration Basin Volume, MGD}) \quad (8.34)$$

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$$[(\text{Return Sludge VSS, mg/l})(\text{Waste Sludge Flow MGD}) \times 8.34] / [(\text{Effluent VSS, mg/l})(\text{Effluent Flow, MGD}) \times 8.34]$$

5. Sludge Density Index (SDI). The rate that activated sludge solids settle to the bottom of a final settling tank depends on the settling characteristics of the sludge. These characteristics are determined by a simple settling test, the results of which can be used to determine the SDI. A 1,000 ml sample is collected from the aeration tank and allowed to settle for 30 minutes in a 1,000 ml graduated cylinder. The volume of settled sludge is read at the end of the 30 minutes.

$$\text{SDI} = \frac{\text{MLSS (mg/l)}}{\text{ml of settled sludge after 30 min settling} \times 10}$$

A good Sludge Density Index is about 1.0. A sludge with an index of 1.5 is dense and settles quickly. An index of less than 1 means a lighter sludge which settles slowly.

6. Sludge Volume Index (SVI). This index is also used to reflect the settling characteristics of activated sludge, but is defined as:

$$\text{SVI} = \frac{\text{ml of settled sludge after 30 min settling} \times 1,000}{\text{MLSS (mg/l)}}$$

In this case, the lower the SVI, the more dense the sludge. An SVI of 100 or less is generally considered a good settling sludge.

7. Microscopic Examination. Microscopic examination of the MLSS can be a significant aid in the evaluation of the activated sludge process. The presence of various microorganisms within the sludge floc can rapidly indicate good or poor treatment. Protozoa play an important role in clarifying the wastewater and act as indicators of the degree of treatment. The protozoa eat the bacteria and help to provide a clear effluent. The presence of rotifers is also an indicator of effluent stability. A predominance of protozoa (ciliates) and rotifers in the MLSS is a sign of good sludge quality. The presence of filamentous organisms and a limited number of protozoa is characteristic of a poor quality activated sludge. This condition is commonly associated with a sludge that settles poorly.

### 3.2.6.5 Total Solids Inventory Approach

This technique for process control is used by many operators because it is simple to understand and involves a minimum amount of laboratory control. The MLSS control technique usually produces good quality effluent as long as the incoming wastewater characteristics are fairly constant with minimal variations in influent flow and organic loading rates.

With this technique, the operator tries to maintain a constant MLSS concentration in the aeration tank to treat the incoming wastewater organic load. To put it in simple terms, if it is found that a MLSS concentration of 2,000 mg/l produces a good quality effluent, the operator must waste sludge from the process to maintain that concentration. If the MLSS level increases above the desired concentration, more sludge is wasted until the desired level is reached again.

When using the total solids inventory approach for process control, the operator should take into account the volume of solids in the aeration tank and in the clarifier, if a significant blanket level is normally maintained.

### 3.2.6.6 Sludge Age As A Control Parameter

Sludge age, or Mean Cell Residence Time (MCRT), is a process control technique available to the plant operator. Basically, the sludge age expresses the average time that a microorganism will spend in the activated sludge process. The sludge age value should be selected to provide the best effluent quality. This value should correspond to the loading for which the process is designed. The operator must find the best sludge age for his process by relating it to the organic loading as well as the effluent COD, BOD, and SS concentrations.

This is an important parameter because the amount of time that the microorganisms are given to break down the waste products has a significant effect on effluent quality. Generally speaking, sufficient time must be permitted for the microorganism to be in contact with the waste to accomplish treatment. If too little time exists, the biological system may have insufficient time to degrade the wastes, resulting in poor quality effluent. If too much time is allowed, the microorganism will deplete the food supply available and begin to die off, resulting in a higher fraction of nonactive biological material in the sludge and a resultant loss of "fine" solids in the effluent. Sludge age also

directly affects solids settling in the secondary clarifier. A young sludge is generally in a high growth rate phase which results in a dispersed growth biological population characterized by poor settling. An old sludge is characterized by low activity and dense floc which settles rapidly with little filtering action as it settles.

The data required for calculating sludge age is as follows:

- Aeration basin MLSS, mg/l
- Aeration basin volume, mg
- RAS SS, mg/l
- Effluent flow, mgd
- Effluent SS, mg/l
- WAS flow, mgd

The determination of the proper target sludge age for the process at any one time is the greatest challenge for the operator. The operator must determine the best sludge retention time for his process by using best judgment in the interpretation of results from other process indicators such as observations of the aeration tanks and clarifiers, as well as final effluent quality. That sludge age which gives the best results will change during the year in relation to external influences such as temperature. Longer sludge ages will be needed in colder weather when the bacterial culture is less active. At this time you will need more bacteria to do the same amount of work.

The operator should make his changes in sludge age slowly and cautiously and only change the sludge age one day at a time. Personnel should not increase or decrease the wasting rate more than 15 percent from one day to the next. Allow at least three sludge ages to let the process settle down before determining the extent of change in the process that has taken place from a one day's change in sludge age before making any further changes. In other words, it takes three sludge ages for the process to reach a steady state after a one-day change in sludge age.

### **3.2.6.7 Establishment Of Desirable MLSS Ranges**

As stated above, the determination of a desirable sludge age or solids inventory level is based on a number of factors, including organic loading, effluent standards, and

seasonal variables. Generally, MLSS levels are maintained at lower concentrations in the summer and higher concentrations in the winter.

The lower MLSS levels in the summer months are related to the increased activity of the microorganisms at higher temperatures. During the winter months, the activity of the microorganisms is lower, requiring more biomass to treat the incoming waste.

MLSS levels should also take into consideration the organic loading to the treatment plant. Higher organic loadings to the plant will require a higher MLSS level to assimilate the incoming waste. For this reason, food to microorganism ration (F:M) should be calculated for the treatment plant on a regular basis.

### **3.2.6.8 Monitoring Sludge Blanket Depth**

Monitoring the depth of the sludge blanket in the clarifier is the most direct method available for determining the RAS flow rate. The blanket depth should be kept to less than one-fourth of the clarifier sidewall water depth. The operator must check the blanket depth on a routine basis, making adjustments in the RAS to control the blanket depth.

If the depth of the sludge blanket is increasing, an increase in the RAS flow can only solve the problem on a short-term basis. Increases in sludge blanket depth may result from having too much activated sludge in the treatment system, and/or because of a poorly settling sludge. Long-term corrections must be made that will improve the settling characteristics of the sludge or remove the excess solids from the treatment system. If the sludge is settling poorly due to bulking, the environmental conditions for the microorganisms must be improved. If there is too much activated sludge in the treatment system, the excess sludge must be wasted.

Measurements of the sludge blanket depth in the clarifier should be made at the same time each day (or each shift). The best time to make these measurements is during the period of maximum daily flow because the clarifier is operating under the highest solids loading rate. The sludge blanket should be measured daily, and adjustments to the RAS rate can be made as necessary. Adjustments in the RAS flow rate should only be needed occasionally if the activated sludge process is operating properly.

An additional advantage of monitoring the sludge blanket depth is that a problem, such as improperly operating sludge collection equipment, will be observed due to irregularities in the blanket depth. A plugged pickup on a clarifier sludge collection system would cause sludge depth to increase in the areas where the improperly operating pickups are located.

### 3.2.6.9 Sludge Wasting Strategy

Control of an activated sludge process is achieved through the wasting of excess sludge from the system. Success or failure in operating an activated sludge plant depends on proper control of the mass of active organisms in the plant. The objective of wasting activated sludge is to maintain a balance between the microorganisms and the amount of food as defined by tests such as chemical oxygen demand (COD) or biochemical oxygen demand (BOD). It is known that when the microorganisms remove BOD from wastewater, the amount of activated sludge increases (microorganisms grow and multiply). The rate at which these microorganisms grow is called the growth rate and is defined as the increase in the amount of activated sludge that takes place in one day. The objective of sludge wasting is to remove just that amount of older microorganisms equal to the new growth. When this is done, the amount of activated sludge formed by the microorganism growth is balanced by that which is removed from the process. This therefore allows the total amount of activated sludge in the process to remain somewhat constant. This condition is called "steady-state" which is a desirable condition for operation. However, steady-state can only be approximated because of the variations in the nature and quantity of the food supply (BOD) and of the microorganism population.

Wasting of the activated sludge is normally accomplished by removing a portion of the RAS flow. An alternate method for wasting sludge is from the mixed liquor in the aeration tank. There is a much higher concentration of suspended matter in the RAS than there is in the mixed liquor. Therefore, when wasting is practiced from the mixed liquor, larger sludge handling facilities are required. Wasting from the RAS takes advantage of the gravity settling and thickening of the sludge that occurs in the secondary clarifier. However, wasting from the mixed liquor has the advantage of not wasting excessive amounts of sludge because of the large quantity of sludge involved.

Wasting of the activated sludge can be done on an intermittent or continuous basis. The intermittent wasting of sludge means that wasting is conducted on a batch basis from day to day.

Intermittent wasting of sludge has the advantage that less variation in the waste sludge concentration will occur during the wasting period, and the amount of sludge wasted will be more accurately known. The disadvantages of intermittent wasting are that the sludge handling facilities in the treatment plant may be loaded at a higher hydraulic loading rate and that the activated sludge process is out of balance for a period of time until the microorganisms regrow to replace those wasted over the shorter period of time.

It is the objective of process control to approach a particular steady state in the activated sludge system. Proper control of the WAS will help provide this steady state while producing a high quality effluent with minimum operational difficulties.

### **3.2.6.10 Oxygen (DO) Uptake Rate**

A simple, but valuable, test the operator can use to monitor the status of the plant is the DO uptake rate test. This is a quick and easy procedure that allows the plant operator to assess the activity of the microorganisms in his biological system. By measuring the rate at which DO is used in a sample of mixed liquor collected from the aeration basin and comparing the results with normal readings for the plant, the operator can determine if the microorganisms are more active than usual or if they are being inhibited.

The plant operator should measure the DO uptake rate in the aeration basin each day so that a "typical" uptake rate for the treatment plant can be identified. This normal value should be established based on readings taken during times when the plant is operating efficiently. An uptake rate lower than normal would indicate low activity, and a high rate would indicate high activity. A low uptake rate in the aeration basin is an indication of impending problems. Lower than normal influent BOD loadings, too low or high a pH, low DO levels, or the presence of toxic material will cause low DO uptake rates. A high oxygen uptake rate indicates higher BOD loadings to the plant than usual. The DO uptake test can be used as a tool to alert the operator of impending problems and give him time to make the necessary adjustments before the performance of the plant is adversely affected.

### 3.2.6.11 Oxygen Uptake Rate Determination

#### A. General

This test measures the rate at which activated sludge organisms use available oxygen.

#### B. Apparatus

1. DO meter with membrane probe.
2. BOD bottles.
3. Stopwatch or timepiece.
4. Magnetic stirrer and stir bars.
5. Necessary assorted glassware.

#### C. Procedure

1. Calibrate meter according to manufacturer's instructions.
2. Shake freshly collected sample vigorously in bottle with air space to increase the DO concentration.
3. Place a stir bar into the bottom of a BOD bottle. Pour sample to overflowing in bottle. Insert DO probe and place bottle on magnetic stirrer with vigorous stirring.
4. When DO reading stabilizes, read and record initial DO and start timer. Record DO readings at intervals of 1 minute. Read and record DO for 15 minutes or until DO drops to 1.0 mg/l DO.

#### D. Calculations

$$\text{Oxygen Uptake Rate (OUR)} = \frac{\text{DO initial} - \text{DO final}}{\text{time interval}} \times 60 \text{ (min/hr)}$$

### 3.2.6.12 Settleability Tests

One of the best process monitoring tools available to the operator is the 30-minute settling test. This test is valuable because it not only helps the operator determine if his plant is running efficiently, but, if problems do exist, it also can help him locate the source of those problems. This is extremely important and time-saving to the operator

because once he knows the problem source, he can concentrate his efforts on conducting tests and investigating probable problem causes which are specific to that area of the plant.

For instance, if during the 30-minute settling test the MLSS settle well in the 2-liter settleometer, but are not settling well in the clarifier, then the problem is probably in the clarifier. Poor settling in the clarifier could be caused by too high a sludge blanket, denitrification, equipment malfunction, etc. On the other hand, if the MLSS do not settle well in the 30-minute settling test, then you wouldn't expect them to settle well in the clarifier, and the problem area is probably the aeration basin. Some typical problems specific to the aeration basin include high DO levels, nitrogen or phosphorous deficiency, low pH, low DO, improper F/M ratio, high BOD loadings, etc. The 30-minute settling test is a reasonable approximation of what is happening in the secondary clarifiers. Through careful observation of the settling rate and sludge quality, the operator can identify problems which may be occurring in the system. Among the types of final clarifier settling problems the 30-minute settling test can help identify are:

Type	Symptoms	Cause
Sludge Bulking	Large floc distributed throughout the clarifier; poor compaction in sludge blanket; microexamination indicates predominance of filamentous organisms	Organic overloading, incorrect F/M ratio, nutrient (N)(P) deficiency
Sludge Rising	Biological solids refloat to the clarifier surface after settling to the bottom	Too long sludge detention time in clarifier, resulting in gas formation due to septicity and/or denitrification
Deflocculation	Small, buoyant floc; turbid supernatant	Toxicity, nutrients deficiency, organic shock loads, anaerobic conditions
Straggler Floc	Small, light floc; clear supernatant	Low sludge age
Pin Floc	Small, dense floc, turbid effluent, rapid settling floc	High sludge age

### 3.3 SECONDARY CLARIFICATION

#### 3.3.1 Introduction

Clarification refers to any of several treatment processes which are used to remove suspended solids particles from the wastewater. The removal of suspended solids can be important for at least three reasons. First, most treated wastewater discharges are permitted with strict limits on the amount of suspended solids that the effluent can contain so as to reduce the environmental impact of these solids (such as excess siltation in receiving streams). Second, many of the suspended solids in wastewater are organic in nature and will cause a higher oxygen demand (biochemical or chemical) in the effluent or subsequent treatment processes unless they are removed. And third, the presence of large amounts of suspended solids can cause problems in downstream treatment processes, including the sedimentation and accumulation of solids in tanks, channels, or pipelines.

For these reasons, gravity clarifiers are often used at the beginning, end, and sometimes even the middle of process trains for wastewater treatment. These solids removal units are sometimes referred to as primary, secondary, tertiary, or final clarifiers, depending on their location and function in the treatment system. Basically, the purpose and operation of each of these units is the same, although the settling characteristics of the solids to be removed are often quite different. Since the settling characteristics of solids particles will vary with the wastewater and the treatment system, the operation of a clarification unit should be based on an understanding of the theory of the gravity clarifiers and the variables which affect their efficiency. The Shaw AFB WWTP utilizes secondary clarifiers.

#### 3.3.2 Theory of Operation

Most of the suspended solids particles present in wastewater have a density that is either greater or less than that of water. As a result, these solids will tend to either sink or float under quiescent (still) conditions. It is for this reason that wastewater collection and treatment systems are designed to insure a turbulent flow of wastewater that will keep these solids particles in suspension until they reach an appropriate solids removal process, such as a grit chamber or gravity clarifier. A gravity clarifier is simply a large volume tank that is designed for efficient solids removal. It includes a system for the withdrawal of settled or floating solids, and it often has baffles and weirs to ensure that quiescent conditions exist and to minimize any short-circuiting that would reduce solids

removal efficiency. Clarifiers are designed to remove a large portion of those particles that have been allowed to pass through grit chambers.

For purposes of discussion, clarifiers are said to have four zones: inlet, clarification, sludge, and outlet. The liquid to be clarified is admitted to the tank through the inlet zone. Separation of the solids from the liquid takes place in the relatively quiescent clarification zone. The clarified effluent is then removed through the outlet zone. Separated solids are allowed to accumulate, compact, and are then withdrawn from the sludge zone.

As previously mentioned, suspended solids are removed in a gravity clarifier by virtue of the difference between their density and that of the surrounding wastewater. Density simply refers to the weight of an object or a material that has a known volume. For example, the density of pure water at 60°F is approximately 62.4 pounds/cubic foot. Sometimes density is expressed using another term, called specific gravity. The specific gravity of a material is equivalent to its weight divided by the weight of an identical volume of pure water. Pure water has a specific gravity of 1.0 by definition. Therefore, an object that has a density of 124.8 pounds/cubic foot (twice that of pure water) would have a specific gravity of 2.0. Regardless of how it is expressed, any object with a specific gravity (or density) greater than water will tend to sink, while an object that is less dense than water (specific gravity less than 1.0) will tend to float. And, of course, a particle that has the same density as water (that is, it weighs the same amount as the water it displaces) will neither sink nor float.

The rate at which solids particles settle (or float) depends on the amount of difference between their density and that of the wastewater. Particles that have a density much greater than water will settle more rapidly than those with a density only slightly greater than water. Likewise, a particle that is slightly less dense than water will rise more slowly than a particle that is much less dense than water. This is an important consideration, since many of the settleable suspended solids particles typically found in wastewater treatment plants are only slightly more dense than water. The specific gravity of these particles is often within the range of 1.00 to 1.05. At the same time, there may also be solids present that have specific gravities much greater than water (in the range of 1.1 to 2.0) which will rapidly settle out and accumulate in process tankage and piping upstream of clarification, unless turbulent flow conditions are maintained.

Two other factors affect the rate of solids settling (or floating). These are (1) particle size, or mass, and (2) particle shape. In general, a larger particle (that is, one having a greater mass) will sink or rise faster than a smaller particle having the same density. Some particles, called colloids, are in fact so small that they cannot be separated from water using gravity alone and must first undergo coagulation and flocculation to increase their size so that they can be removed in a gravity clarifier.

In addition to particle size, the shape of a particle is also important. A particle that is perfectly spherical in shape will settle faster than a particle made of the same material and having the same mass (total weight) that is more irregularly shaped. The reason for this is that there is more drag or friction created by irregularly shaped particles as they settle through water, which tends to slow descent. As an example of this, imagine two identical pieces of paper that are dropped to the floor. Both pieces will fall in about the same amount of time. However, if one piece of paper is tightly wadded up and the other is lightly crumpled, the tightly wadded piece will fall faster than the lightly crumpled piece, even though they have the exact same mass and density. The reason for this is that the lightly crumpled piece of paper is subject to more friction or drag when falling through the air, which makes it fall more slowly.

To summarize, suspended solids particles can be separated from wastewater under the force of gravity by virtue of the difference between their densities and that of the wastewater. The rate at which these particles settle (or rise) depends on the magnitude of this density difference as well as upon the size (mass) and the shape of the solids particles. Therefore, any factors which change the relative densities of the suspended solids particles and the wastewater, or any factors which change the size or shape of the solids particles, will affect the rate of solids settling during gravity clarification. The settling rate (expressed in terms such as feet per hour) is important since it determines how well the clarifier will perform. It shows what fraction of the influent suspended solids will be captured and removed.

A factor which greatly affects settling rate is hydraulic residence time. Imagine a solids particle that settles at a rate of 10 feet per hour under quiescent conditions. If this particle were placed into a tank of water near the surface, it would settle at a constant rate of 1 foot every 6 minutes (10 feet/hour) until it reached the bottom of the tank. If the

tank contained 10 feet of water, this would take 1 hour or less, depending on the original depth at which the solids particle was placed into the tank.

Now imagine the same particle being placed into one end of a 200-foot long tank in which water is flowing horizontally at a constant rate of 2 feet per minute. (For this discussion, we will ignore effects of the inlets and outlets to the tank and assume that the flow is perfectly distributed from top to bottom and that it travels only horizontally). At this flow rate, we can assume that the water in the tank is not turbulent enough to keep the particle in suspension and that the particle will still settle at a rate of 10 feet/hour. What occurs is illustrated in Figure 3.1. It will take 100 minutes (200 feet divided by 2.0 feet/minute) for the water to travel through the tank. If, during its diagonal course of travel, the particle settles vertically toward the bottom of the tank at a rate of 1.0 foot in 6 minutes, it will rest on the floor of the tank in 60 minutes if the tank is 10 feet deep. In other words, if the particle settles at the rate of 10 feet in 60 minutes, it should settle in the first 120 feet of the tank.

Now consider that the horizontal flow rate is doubled to 4.0 feet per minute, as shown in Figure 3.1b. In this case, it will only take 50 minutes for the water to pass through the tank. If the same particle enters the tank at the water surface, it will not have time to settle to the bottom of the tank before it reaches the other end, because its vertical settling velocity is only 10 feet per 60 minutes and the tank is 10 feet deep.

From the previous discussions, it should have been obvious that hydraulic residence time (HRT) has an important effect on whether a particle with a given settling rate will be captured or not. In general, with a longer residence time, more of the slower settling particles will settle out.

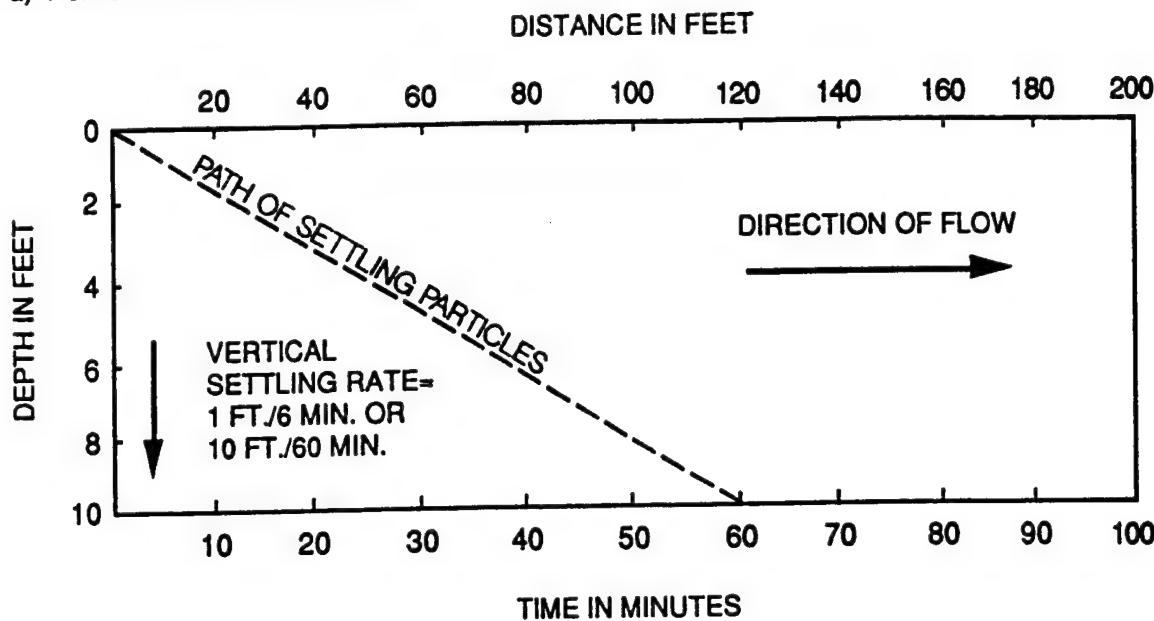
### 3.3.3 Density Currents

Short-circuiting can occur in settling basins if the incoming flow has a higher temperature or density than the mass of liquid in the basin. This condition is usually evidenced by violent rolling of masses of liquid with entrained solids to the surface. Short-circuiting can occur when the temperature suddenly increases 1° to 2°F with light flocculant-type solids.

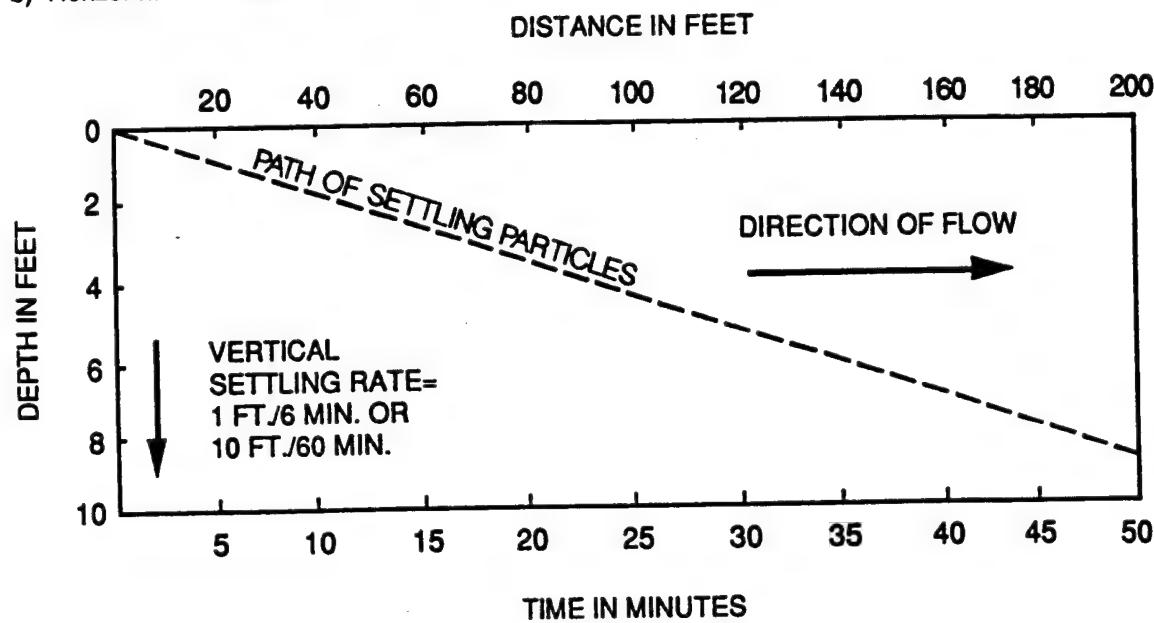
Figure 3.1

## IDEALIZED PARTICLE SETTLING IN A GRAVITY CLARIFIER

a) Horizontal Flow Rate = 2 ft./min.



b) Horizontal Flow Rate = 4 ft./min.



If the incoming flow is colder than the water in the basin, it can flow along the bottom at a high velocity and reduce the efficiency of solids removal.

### 3.3.4 Operating Parameters

There are a number of operating parameters important to the efficient operation of clarifiers.

#### 3.3.4.1 Hydraulic Loading

Hydraulic loading on a clarifier is generally measured in terms of surface loading rate. Surface loading rate is defined as the average influent flow (gallons per day) divided by the surface area of the clarifier. It is a measure of the upward velocity of flow and must be kept low enough to prevent flow of sludge over the weirs. Surface loading rate is calculated as:

$$\text{Surface Loading Rate, GPD / ft}^2 = \frac{\text{Influent Flow Rate, GPD}}{(\text{Clarifier Surface Area, ft}^2)}$$

Secondary clarifiers will operate efficiently when the loading rate is in the range of 400-800 gpd/ft<sup>2</sup>.

#### 3.3.4.2 Detention Time

Detention time is defined as the average time a particle of water is in the clarifier. Detention time is calculated as:

$$\text{Detention Time, hrs} = \frac{\text{Clarifier Volume, Gal})(24 \text{ Hrs / Day})}{\text{Influent Flow Rate, GPD}}$$

Secondary clarifiers will operate efficiently when the detention time is between 1.5 and 2.5 hours. If detention time is too short, a smaller portion of the suspended solids will settle, and removal efficiency will decline. If detention time is too long, removal efficiency will not improve materially and can lead to wastewater becoming septic in the clarifier.

#### 3.3.4.3 Weir Overflow Rate

Weir overflow rate is defined as the average influent flow (gal/day) divided by the weir length. It should be kept low enough to provide quiescent conditions in the clarifier.

Weir overflow rate is calculated as:

$$\text{Weir Overflow Rate, GPD / ft} = \frac{\text{Influent Rate, GPD}}{(\text{Weir Length of Clarifier, ft})}$$

Weir loadings of secondary clarifiers will generally be around 10,000 GPD per linear foot.

#### 3.3.4.4 Solids Removal

Solids must be removed from clarification tanks or, eventually, the settled sludge level will increase to the point that solids are washed out with the tank's effluent. Solids may be removed continuously or in a batch method. Solids which settle in secondary clarifiers are sometimes removed continuously and sometimes in batches depending on the plant size and type of treatment process.

### 3.4 FILTRATION

Filtration is a separation process used to remove suspended solids present in the wastewater. In the filtration process, wastewater is passed through a bed of porous material which separates the solids from the wastewater. Generally, filtration is used after clarification to further reduce suspended solids concentrations in the final effluent. In deep granular filters, the solids are removed through an adsorption/disposition process as the wastewater passes through a deep bed of granular material. In precoat and cartridge filters, the solids are removed through a mechanical straining process as the wastewater passes through a thin layer of filter media.

#### 3.4.1 Theory of Operation

Filtration involves the passage of water through porous media with a resulting removal of suspended solids. A number of mechanisms, some chemical and some physical, are involved in the solids removal process. The predominant mechanisms are straining, disposition, and adsorption. The dominant mechanism for a given filter depends upon the physical and chemical characteristics of the wastewater and the filter.

Straining involves removal of particles, either at the filter surface or within the interstices of the filter media, and is affected by the filter media and particle size and the filtration rate. For both precoat filters and cartridge filters, the predominant removal mechanism is assumed to be straining, which occurs at the surface of the filter media. Although straining also occurs to a limited degree in deep granular filters, primarily within the interstices of the media, its importance is generally minimized during design because it leads to rapid buildup of head loss which limits the length of filter runs.

Disposition and adsorption within the filter bed are the predominant solids removal processes in deep granular filters. Disposition involves gravitational settling, diffusion, and interception and is affected by the physical characteristics and the size of the media, the filtration rate, the fluids temperature, and the size and density of the suspended solids. Adsorption relies upon the attachment of the suspended solids particles to the filter media. The amount of surface available for adsorption is enormous, roughly 3,000 to 5,000 square feet per cubic foot of media. Adsorption relies upon attachment and is affected by use of coagulants, the characteristics of the wastewater (especially particle size), shear strength and driving force, adhesiveness of the suspended solids floc, and the characteristics of the filter media.

### 3.4.2 Driving Force

There are three basic filter operating methods, and they differ in the way that the driving force is applied across the filter. These methods are referred to as constant-pressure filtration, constant-rate filtration, and declining rate filtration. For constant-pressure filtration, a constant driving force is applied across the filter for the entire filter run. Because filter resistance is lowest at the start, the flow rate is at its peak. As solids are captured, filter resistance increases and the rate of flow decreases. This operating method is seldom used because a large flow equalization basin is required to deal with the change in flow during the filter run.

In constant-rate filtration, a constant pressure is applied to the filter, but filter resistance is modulated through control of the flow rate using a flow control valve. At the start of the filter run, the flow control valve is nearly closed, then as solids accumulate, the flow control valve is opened to compensate for the increase in the filter resistance. While storage capacity is minimized, the initial and operating costs for the rate controller are high and water quality is lower than with declining rate filtration. The constant rate system is also wasteful of available head because excess head is lost in the controller. Additionally, the control valve may set up high frequency surges in the filter bed.

Declining-rate filtration utilizes a bank of filters to moderate the effect of increases in filter resistance. As the filters served by a common header become dirty, the flow through the dirtiest filter drops rapidly, increasing the driving force so that the other filters can handle additional flow from the dirtiest filter. This method provides a more gradual decrease in the rate of flow over the filter cycle and provides a better effluent quality than with constant rate operation. As with constant pressure filtration, a large upstream water storage is needed.

### 3.4.3 Backwashing

Once filter resistance exceeds the available driving force, the accumulated solids must be removed from the filter. In cartridge filters, this process requires dismantling of the filter housing and replacement of the filter cartridges.

Backwashing of deep granular filters involves reversing the flow through the filter at a rate sufficient to expand the filter bed. The deposited material is then dislodged by

hydraulic shearing action of the water and abrasion of the grains of filter media. Where cleaning is inadequate, mud balls--masses of filtered solids--develop and, over time, will grow and sink deeper into the filter bed, increasing head loss and decreasing effluent quality. Where backwash rates are inadequate to thoroughly clean the filter, longer duration backwashes must be used (5 to 10 or at an extreme, 15 minutes) to provide the necessary cleaning. Air scour is often used to assist in backwashing.

## 3.5 SLUDGE STABILIZATION

### 3.5.1 Introduction

Sludge stabilization processes are key to the reliable operation and performance of any wastewater plant. It is not inappropriate to think of a wastewater plant as a sludge factory. In a sludge stabilization process, several factors must be considered, including quantity of sludge to be treated, and ultimate disposal of the sludge.

Sludge stabilization is basically a process to either reduce volatile solids, significantly reduce pathogens, or prepare the sludge for further processing.

### 3.5.2 Aerobic Sludge Digestion

Sludge stabilization processes are key to the reliable performance of any wastewater treatment plant. Handling sludge produced as a by-product of wastewater treatment operations is often a technical challenge.

The stabilization of wastewater treatment plant sludges during the aerobic digestion process can be defined as the destruction of degradable organic components of the sludges by aerobic, biological mechanisms. The aerobic digestion process represents a continuation of the suspended growth biological treatment process and is based on theoretical concepts similar to those of the activated sludge process.

The objectives of the aerobic digestion process include production of a stable end product by oxidizing sludge organisms and other biodegradable organics, reduction of the sludge mass and volume, and conditioning of the sludge for further processing. Basically, the process involves the aeration of waste solids in the absence of additional nutrients for extended periods of time. In the absence of an external source of nutrients, endogenous respiration occurs with a subsequent decrease in volatile suspended solids.

During the digestion process, cell tissue is oxidized aerobically to carbon dioxide, water, and ammonia or nitrates. Because the aerobic oxidation process is exothermic, a net release of heat occurs during the process. Although the digestion process should theoretically go to completion, in actuality only about 75 to 80 percent of the cell tissue is oxidized. The remaining 20 to 25 percent is composed of inert components and organic compounds that are not biodegradable. The material that remains after the full completion of the digestion process exists at such a low energy state that it is essentially biologically stable. Consequently, it is suitable for a variety of final disposal options.

One of the advantages of the aerobic digestion process is its relative simple operation. As long as the biological environment (temperature, pH, absence of toxic substances, etc.) is maintained suitable to support life, the aerobic digestion process is essentially self-sustaining.

The primary disadvantage commonly attributed to the aerobic digestion process is the higher power cost associated with oxygen transfer. Recent developments in the aerobic digestion process, such as highly efficient oxygen transfer equipment, and research into operation at elevated temperatures may reduce this concern. Other disadvantages frequently cited include the reduced efficiency of the process during cold weather and the mixed results achieved during mechanical dewatering of aerobically digested sludges.

### **3.5.2.1 Operation**

Aerobic digesters can be operated in batch or continuous mode. The supernatant obtained after solids separation is normally discharged back to the treatment plant. While the quality and quantity of this supernatant on the treatment plant must be evaluated, the characteristics of the supernatant are relatively innocuous.

Foaming problems are common in aerobic systems, especially in systems using surface aeration devices. Foaming problems are generally caused by high organic loading rates during summer periods. Growth of filamentous bacteria can also cause foaming problems. Foaming may also occur in the spring and fall while the microorganisms reacclimate to summer or winter temperatures.

### **3.5.2.2 Dewatering**

The dewatering characteristics of digested sludge decreases as the sludge age increases. Optimal dewaterability seems to occur after 1 to 5 days of aeration.

The dewaterability is also affected by the degree of mixing provided during the digestion process. High degrees of mixing will break the biological floc, thereby reducing the dewaterability.

### **3.5.3 Lime Stabilization**

As part of the new federal sludge regulations contained in 40 CFR 503, land applied sludge must undergo a PSRP (process to significantly reduce pathogens). In order to

accomplish this at the Shaw AFB, a lime stabilization system has been added to the sludge treatment section of the process.

In this system, sufficient lime is added to raise the pH of the sludge to 12.0, and this pH value is held in the vessels for a minimum of 2 hours. After this time period, this stabilized sludge is hauled to the Shaw AFB land application site and applied to soil.

## 3.6 SLUDGE DEWATERING

### 3.6.1 Introduction

Sludge is a major by-product of domestic wastewater treatment. Its disposal is a problem comparable in importance and magnitude to the liquid wastewater treatment problem. Sludge dewatering is an economic necessity to reduce the sludge volume requiring disposal and to retard biological decomposition.

The objective of sludge dewatering is to reduce the capital and operating costs associated with its ultimate disposal by substantially reducing the sludge volume. Dewatering a sludge from 5 percent to 25 percent solids concentration reduces the sludge volume to approximately one-fifth (20 percent) of its original volume.

The sludge dewatering concept is embodied within a category of processes designed to extract water from sludge. In dewatering systems, sufficient water is extracted from the sludge so that it assumes a nonfluid character. No longer a liquid, dewatered sludge is characterized as a damp solid. An arbitrary index used in the wastewater industry to distinguish between dewatered sludge and thickened sludge is a minimum 15 percent solids content for dewatered sludge. It is important to note, however, that the physical characteristics displayed by sludges of a given moisture content will vary, depending on sludge type and conditioning.

Sludge dewatering may be accomplished by a number of natural and mechanical means that incorporate the use of gravity, evaporation, vacuum, centrifugal force, pressure, capillary action, or a combination of any of the above.

Prime considerations in the selection of sludge dewatering methods are cost, availability of disposal site, aesthetic factors, and the environmental impact of the disposal approach on people.

### 3.6.2 Sludge Drying Beds

Despite a variety of mechanical methods available for sludge dewatering, approximately two-thirds of treatment plants in the United States have sludge-drying beds such as those utilized at the Shaw WWTP. By using this procedure, a sludge can be dried to about a 75 percent or less moisture content in a few weeks of dry weather. Such a sludge is conveniently handled with a shovel or garden fork. The area required for sludge drying beds is primarily determined by climatic conditions.

The dewatering of the sludge on sand beds occurs by filtration of the water through the sand and evaporation of the water from the sludge surface. Filtration is usually accomplished on digested sludge in 1 to 2 days. This is dependent upon the characteristics of the sludge and the depth to which the sludge is placed on the bed. After most of the water is filtered off, the sludge then dries to an equilibrium moisture content with the surrounding air. This final moisture content depends upon the temperature and relative humidity of the air and the nature of the water content. Bound water retained in capillaries and in cell walls will result in a high final moisture content. A high bound-water content is representative of raw or partially digested sludge. Well-digested sludge possesses a low bound-water content and is easily dewatered on sand beds.

Sludge-drying beds normally consist of 4 to 6 inches of sand over 8 to 12 inches of gravel or stone. The bed is drained by tile underdrains placed in the gravel about 6 to 12 feet apart. The spacing of the underdrains depends on the drainage characteristics of the subsoil. The underdrainage may be returned to the head of the plant. The side walls of the beds are made of concrete. The side walls are about 12 inches high and the beds are filled to a depth of 8 to 10 inches. Several smaller beds serve the purpose better than one large bed. The width of the drying bed is so chosen that the vehicle used for removing the dried sludge can be loaded conveniently. Common values for width are about 20 feet. The length is generally held below 100 feet. Sludge may be expected to flow approximately 100 feet from a single outlet when the bed slope away from the outlet is about 0.5 percent.

## 3.7 DISINFECTION

### 3.7.1 Introduction

From the viewpoint of health, the disinfection process is a very important consideration. It is the unit process that provides a barrier to the transmission of waterborne disease by destruction of pathogens before release of the waste stream to the environment. Disinfection of wastewater effluents has contributed to the dramatic reduction that has occurred through the years in the incidence of waterborne disease outbreaks. Disinfection refers to the selective destruction of disease-causing organisms. All of the organisms are not destroyed in the process. This differentiates disinfection from sterilization, which is the destruction of all organisms.

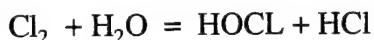
### 3.7.2 Liquid-Gas Chlorine

Chlorine is one of the chemical elements. Commercial chlorine is a liquified gas under pressure. As a liquid, it has a clear, amber color. In a gaseous form, it has a greenish-yellow color and a strong pungent odor. Chlorine is fed as a gas from 150-pound bottles at the Shaw AFB WWTP. Liquid chlorine is about one and one half times as heavy as water, and as a gas it is heavier than air. Chlorine is neither explosive nor flammable; however, it will support combustion. At atmospheric pressure, liquid chlorine boils at about -30°F and freezes at about -150°F. One volume of liquid chlorine, when vaporized, will yield about 460 volumes of gas. When exposed to normal atmospheric pressure and temperature, liquid chlorine will vaporize to a gas.

Chlorine has a very strong affinity for many substances and will react with almost all the elements and with many inorganic and organic compounds, usually with the evolution of heat. At elevated temperatures, it reacts vigorously with most metals. In a moisture-free state at ordinary temperatures, it is relatively non-corrosive. However, in the presence of moisture, it is highly corrosive.

Several reactions will occur simultaneously when chlorine is added to clear wastewater. The reactions are affected by temperature, pH, buffering capacity of the wastewater, and the nature of the chlorinating agent.

When chlorine is added to water the chemical reaction is:



At pH values below 7.5, the hypochlorous acid (HOCl) is the predominant compound, while at pH values above 7.5, the hypochlorite ion (OCl<sup>-</sup>) predominates. Hypochlorous acid is the more effective disinfection agent. The HOCl and OCl<sup>-</sup> available after all reactions have been completed are defined as free chlorine residual.

Wastewater contains many complex substances which will react directly with chlorine. Any ammonia available will react with the HOCl to form chloramines. Chloramines are also disinfecting agents, although not as effective as free chlorine. The chloramine residual is called combined residual.

Before the chlorine and the chloramines can destroy the bacteria, all other direct chemical reactions must be satisfied. The chlorine demand of the wastewater is the amount of chlorine needed to satisfy direct chemical reactions and to produce a minimum residual of chlorine or chloramine.

### 3.7.2.1 Mixing

It is imperative that the chlorine solution and wastewater be mixed as instantaneously and completely as is mechanically possible. This rapid mixing is termed flash mixing and is necessary to assure that chlorine is available to react simultaneously with every chemically active soluble and particulate component of the wastewater.

In the design of the chlorination system, it is important to provide conditions that will limit the release of chlorine or chlorine compounds from solution. This is necessary from an efficiency standpoint and to prevent a health hazard from chlorine gas in the atmosphere. The most essential conditions are (1) that the chlorine distributor should be submerged at least 2 feet below the wastewater level when chlorine water solution is applied and from 5 to 10 feet, depending on amount fed, when chlorine gas is applied with effective diffusion, and (2) that the wastewater flow following the application and adequate mixing of chlorine should not be subjected to excessive turbulence.

### 3.7.2.2 Contact Time

Once chlorine is completely mixed with wastewater, plug flow through the contacting system must be maintained. The more closely a contactor design approaches 100 percent plug flow, the better the performance should be.

Plug flow contacting can be effectively accomplished by proper utilization of outfall lines that should always flow full. Successful contacting can also be provided in open channels, although the rectangular and other compact designs provide more economical use of land in most locations. All contactors should be designed with flow gradients that minimize settling of solids, although some solids accumulation is unavoidable. Solids and any slime accumulations on fluid contact surfaces must be removed at regular intervals. Carelessness in this regard can lead to increased chlorine demand and erratic bacterial quality in the disinfected effluent.

Assuming 95 percent plug flow, a minimum contact time of 30 minutes at maximum design flow is a good guideline for general use. A nominal increase in contact time (under the flow conditions specified) may be advantageous in some situations, but a reduction in the contact time will reduce the margin of safety unless an offsetting increased chlorine concentration is provided.

### 3.7.2.3 Dosage and Residual Control

Successful disinfection with chlorine is extremely dependent on providing rapid response to fluctuating chlorine demand to maintain the chlorine residual at a predetermined desirable level.

Effective disinfection thus requires that there be a defined chlorine residual after a suitable contact period. Because the waste of each community requires a special determination of the dosage that will yield the desired or required chlorine residual, efficient and economical operation demands that the application rate be regulated as often as necessary to insure efficient and economical operation. Only by frequent determinations of chlorine residual can the dosage rate, and thus the effectiveness of disinfection, be satisfactorily controlled. Satisfactory disinfection of secondary wastewater effluents generally can be obtained when the chlorine residuals after 15 to 30 minutes contact are between 0.2 and 1.0 mg/l. A residual of 0.5 mg/l after 15 minutes contact appears to be a reasonable average.

Chlorine residual is the critical factor in disinfection. The chlorine applied must persist long enough to attain the desired coliform reduction. Other factors which are involved in the chlorine disinfection process include pH, temperature, concentration of organisms, and the nature and size of particulate material present.

### **3.7.3 Chlorine Destruction**

To insure that chlorine limits are achieved in the plant, sulfur dioxide in carefully controlled dosages is added to the effluent water as it exits the chlorine contact chamber. These two chemicals combine to reduce the chlorine residual to an acceptable limit.

### 3.8 ADDITIONAL REFERENCES

To enhance the operator's knowledge of the treatment processes at the Shaw AFB wastewater plant, a number of additional references are available. These include:

- Sacramento Course--*Operation of Wastewater Treatment Plants*, Volumes 1 & 2
- Sacramento Course--*Industrial Waste Treatment*
- Air Force Manual AFM 91-32--*Operation and Maintenance of Domestic and Industrial Wastewater Systems*
- *Standard Methods for the Examination of Water and Wastewater*, 18th Edition
- *Manual of Practice OM-9--Operation and Maintenance of Activated Sludge Plants*
- *Manual of Practice 7--Operation and Maintenance of Wastewater Collection Systems*
- *Manual of Practice OM-3--Plant Maintenance Program*
- *Manual of Practice 11--Operation of Wastewater Treatment Plants*
- *Manual of Practice OM-1--Wastewater Sampling for Process and Quality Control*

All of the above manuals of practice (MOP) are available from the Water Environment Federation.

## CHAPTER 4

### SAMPLING AND ANALYTICAL SCHEDULE

#### 4.1 INTRODUCTION

The purpose of the analyses performed in the Shaw AFB WWTP laboratory is to provide data to be used in decision making and fulfill NPDES permit requirements. By relating lab results to the waste treatment operation, the operator can effectively make process decisions, determine the efficiency of the treatment process, identify trends in the process, and determine the causes of plant upsets.

The value of any laboratory result depends on the integrity of the sample. Too often, the sole burden for providing accurate laboratory results rests on the analyst running the sample. However, the method used in obtaining the sample is just as important to the analyst as the analytical procedures he or she follows.

Obtaining a sample for laboratory analysis is based on the assumption that the sample obtained is a part of the whole being measured. This idea is most important because if the sample is not truly representative, all subsequent conclusions, decisions, and actions will be affected by the errors in the sample. Samples must be collected so that nothing is added or lost and that no changes occur during the time between collection and laboratory examination of the sample. Since the design and successful operation of any wastewater treatment plant are dependent upon the results of laboratory analysis, sampling is one of the most critical steps and the one typically introducing the greatest errors in these results. Baseline Guidance Document Criteria samples and other recommended process control samples for the Shaw AFB wastewater plant are presented in Table 4.1. The laboratory location where analyses are to be performed is also presented in Table 4.1.

The validity of the laboratory analysis will depend upon attention to the following details:

1. Be sure that the sample and sampling point will be truly representative of the wastewater.
2. Use proper and acceptable sampling techniques.

**TABLE 4.1**  
**SHAW AFB WASTEWATER TREATMENT PLANT**  
**SAMPLING/ANALYTICAL SCHEDULE**

Parameter	Frequency	Laboratory	Permit Requirement
Influent BOD	2/week	WWTP	
Final Effluent BOD	2/week	WWTP and Contract	Yes
Influent TSS	2/week	WWTP	
Aeration Basin MLSS	2/week	WWTP	
Aeration Basin MLVSS	2/week	WWTP	
Return Activated Sludge	2/week	WWTP	
Secondary Clarifier TSS	5/week	WWTP	
Tertiary Filter Effluent	5/week	WWTP	
Final Effluent TSS	2/week	WWTP and Contract	Yes
Aeration Basins Settleable Solids	4/week	WWTP	
Outfall Dissolved Oxygen (D.O.)	2/week	WWTP	Yes
Aeration Basin D.O.	4/week	WWTP	
Influent pH	Daily	WWTP	
Effluent pH	Daily	WWTP	Yes
Outfall pH	2/week	WWTP	
Influent Temperature	Daily	WWTP	
Outfall Temperature	2/week	WWTP	
Effluent Chlorine Residual	Daily	WWTP	
Outfall Chlorine Residual	2/week	WWTP	Yes
Effluent Ammonia-Nitrogen	2/week	Contract	Yes
Effluent Total Phenols	1/Quarter	Contract	Yes
Digester Total Solids	1/week	WWTP	
Digester Volatile Solids	1/week	WWTP	
Effluent Fecal Coliform Bacteria	2/week	Contract	Yes

3. Be sure that proper sample preservation techniques are followed until the samples are analyzed.

## 4.2 SAMPLING TECHNIQUES AND CONSIDERATIONS

Because of the lack of uniformity of wastewater, attention to the following basic principles will aid in obtaining a proper sample:

1. Sampling points must be selected carefully to assure good mixing of the material to be sampled. Samples should be collected from the main body of flow where the velocity is high and will not be influenced by previous deposits or interfering side currents.
2. Sampling points should be well marked so that all samples are taken from the same place. In addition, proper sampling equipment should be available, and adequate safety precautions must be observed.
3. Sampling containers should be rinsed two or three times with the water to be collected before sample collection except when biological samples are to be collected or when the sample bottle contains a chemical preservative.
4. Sample lines should be well flushed before sample collection to ensure that the sample is representative of the supply source. If, for example, a sample line will hold a volume of 3 gallons from supply source to sample tap, then a minimum of 5 gallons of wastewater should be drained from the line before the sample is obtained.
5. Appropriate container for the type of analysis to be run should be used (see Table 4.2).
6. Proper sample preservation techniques should be used (see Table 4.2).
7. Adequate volume of sample must be obtained. Samples should be large enough for the required analysis plus an additional amount for a second confirmation analysis in case of doubtful results (see Table 4.2).
8. Sample containers should be labeled as to date, time, exact sample point, type of sample (grab or composite), sample collector, preservatives, if any, and any other information that might have influence on the methods of analysis, results, or interpretation of those results.
9. Composite sample reservoirs should be well-mixed before samples are obtained from them, and all samples should be mixed again before analysis.

10. The appropriate sample type (grab or composite) must be obtained depending on the type of analysis to be run. Reference Table 4.4.
11. Samples should be analyzed as soon after collection as possible for greatest reliability. Some tests must be run on site because the sample composition will change before the sample reaches the lab.
12. Sampling times for grab samples should be selected to represent typical weekday averages or varied from day to day to represent a cross-section of the waste characteristics. Remember, a sample taken early Monday morning may, in actuality, be a sample of the waste from Sunday night.
13. Where necessary to avoid an excess of floating material, the mouth of the collecting container should be held a few inches below the surface level.

#### **4.2.1 Grab Samples**

Grab samples are representative of the characteristics of the wastewater at the instant the sample is caught. When it is only possible to collect grab samples, it is preferable that they be collected when the treatment plant is operating at peak flow or organic load conditions. Grab sampling times may be staggered to account for the hydraulic detention time of each unit. If the hydraulic detention time of a process unit is 2 hours, the grab sample of the effluent may be collected 2 hours after the influent sample, thus the samples can be assumed to be representative of the wastewater before and after treatment.

In addition, a grab sample may be taken for any of the following reasons:

1. The waste stream to be measured does not flow on a continuous basis.
2. A "slug" or batch discharge or other unusual or undesirable situation is observed.
3. A condition or operation is of short duration and quite uniform.
4. The waste characteristics are relatively constant over extended periods of time.
5. To determine if a composite sample is averaging out extreme changes in a parameter (i.e., pH) that can be detrimental to the treatment process.
6. Permit requirements dictate grab samples for analyses of selected parameters.

#### 4.2.2 Composite Samples

A composite sample results from the combination of multiple grab samples on a time or flow proportionate basis over a set time period. The composite sample is useful for analysis of wastewater constituents that do not deteriorate or change over extended time periods with proper preservation and where the average composition of the wastewater is sought. Composite samples provide useful data if the fluctuations in wastewater characteristics are not extreme and tend to minimize the effect of intermittent changes in wastewater characteristics and flow. Currently, samples are manually collected and composited according to flow at the Shaw WWTP. Samples are collected every two hours during periods when the WWTP is staffed.

The best type of composite sample is one in which the volume of each grab sample is in direct proportion to the flow reading at that instant. The following example illustrates the sample volumes to be collected on a 12-hour composite:

Flow Time (MGD) Factor			Sample Volume(ml)	Flow Time (MGD) Factor			Sample Volume (ml)
6am	0.2	100	20	12N	1.4	100	140
7am	0.3	100	30	1pm	1.6	100	160
8am	0.6	100	60	2pm	1.5	100	150
9am	0.9	100	90	3pm	1.3	100	130
10am	1.2	100	120	4pm	1.3	100	130
11am	1.2	100	120	5pm	1.2	100	120

The total volume of samples collected in the above example of a 12-hour composite would have been 1270 ml. If a composite is made from individually collected grab samples, then each of the individual grab samples should be shaken vigorously to provide a uniform mixture before the samples are pooled together. The pooled composite sample should also be thoroughly mixed immediately prior to obtaining a sample for analysis. Failure to do so may contribute to serious errors.

The amount to be collected during a specific sampling period can be calculated using the following formula:

$$\text{Amount of sample to collect} =$$

$$\frac{(\text{Rate of flow, MGD, at time of sampling})(\text{Total sample required, ml})}{(\text{Number of samples collected})(\text{Average daily flow, MGD})}$$

Example Calculation:

Data:

1. Rate of flow at sample time = 2 MGD
  2. Total sample required, ml = 4000 ml
  3. Number of samples to collect = 24
  4. Average daily flow = 1.5 MGD
- Amount of sample to collect =  $\frac{(2\text{MGD})(4000\text{ml})}{24 \text{ (1.5 MGD)}}$
- $$= 222.2 \text{ ml}$$

#### 4.2.3 Automatic Samplers

Automatic samplers are used to collect a series of grab samples on a constant time-constant volume principle or on a flow proportionate basis. The flow proportionate automatic samplers function by collecting a definite volume of sample each time a predetermined number of gallons of wastewater has passed the flow measuring device. This is the recommended approach to flow compositing at the Shaw AFB WWTP.

In selecting automatic samplers and sampler locations, consideration should be given to the following:

1. Resistance of the sampler to the particular types of wastes being treated (i.e., wastes highly acidic or containing organic solvents).
2. Protection of the sampler from corrosive atmospheres, particularly in confined areas containing raw wastes.
3. That the sampler provide sufficient flow velocity in the intake tube to prevent settling of heavier solids particles.
4. That some type of sample-preservation is provided, either refrigeration or ice packs.
5. That sampler placement does not exceed the suction head capabilities of the sampler.
6. That compatible interfacing of the flow meter and sampler is possible.
7. That adequate safety is afforded personnel during recovery of the composite sample.
8. That a purge cycle is available to clean the intake line before and after each sample is collected.

As with all pieces of equipment, preventive maintenance and cleaning schedules should be followed. In particular, the intake tubes should be cleaned regularly to prevent solids buildup and periodic slough-off that can contaminate samples.

## 4.3 OTHER SAMPLING CONSIDERATIONS

### 4.3.1 Sample Preservation

Complete preservation of any sample, regardless of source, is almost impossible and can never be achieved for every constituent in the sample. Preservation techniques can only, at best, retard the biological and chemical changes that inevitably continue after the sample is removed from the source. The methods of preservation are limited and are intended generally to (1) retard biological action, (2) retard hydrolysis of chemical compounds and complexes, and (3) reduce volatility of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration, and freezing.

Table 4.2 shows the various preservatives that may be used to retard changes in samples. Table 4.2 gives types of containers, preferred method of preservation, and holding times for various test parameters.

### 4.3.2 Cleaning Sample Bottles

A common mistake made by those sampling is to use a bottle that has held "unknown" materials as a sample container. Often these containers have held oily or greasy substances which cling to the walls of the bottle and resist rinsing. Only new bottles or bottles that have been cleaned by acceptable methods in the laboratory should be used as sample bottles. It is good practice to designate bottles to be used exclusively to hold particular samples. These containers should be carefully labeled and used for no other purpose. These containers should be thoroughly rinsed before and after each use and periodically cleaned in the laboratory using only authorized laboratory cleaners.

### 4.3.3 Sample Volumes

Adequate volumes must be obtained to perform the desired analysis. The volume collected should be large enough to repeat the procedure if necessary. Never "dump" the remainder of a sample until your results are completed and considered to be satisfactory.

**TABLE 4.2**  
**RECOMMENDED SAMPLING SIZES AND PRESERVATION METHODS**

Determination	Container	Minimum Sample Size mL	Preservation	Maximum Storage Recommended/Regulatory
Alkalinity	P, G	200	Refrigerate	24 h/14 d
Ammonia Nitrogen	P, G	500	H <sub>2</sub> SO <sub>4</sub> , Refrigerate	28 d/28 d
BOD	P, G	1000	Refrigerate	6 h/48 h
Chlorine, residual	P, G		H <sub>2</sub> SO <sub>4</sub> to pH <2	Analyze immediately
COD	P, G		Analyze immediately	28 d/28 d
Fecal Coliform Bacteria	P, G	100	H <sub>2</sub> SO <sub>4</sub> , Refrigerate	6 h/6 h
Metals, general	P(A), G(A)	--	For dissolved metals filter immediately, add HNO <sub>3</sub> to pH <2	6 months/6 months
Chromium VI	P(A), G(A)	300	Refrigerate	24 h/48 h
Nitrogen, Total	P, G	1,000	H <sub>2</sub> SO <sub>4</sub> , Refrigerate	28 d/ 28 d
Nitrates	P, G	100	Refrigerate	48 h/48 h
Nitrites	P, G	100	Refrigerate	48 h/48 h
Oil and Grease	G, wide-mouth calibrated	1000	Add H <sub>2</sub> SO <sub>4</sub> to pH <2, refrigerate	28 d/28 d
Oxygen, dissolved: Electrode	G, BOD bottle	300	Analyze immediately	Analyze immediately
Winkler			Titration may be delayed after acidification	8 h/8 h
pH	P, G	100	Analyze immediately	Analyze immediately
Phosphorus, Ortho	P, G.	100	Filter	48 h/48 h
Phosphorus, Total	P, G.	100	H <sub>2</sub> SO <sub>4</sub> , Refrigerate	28 d/28 d
Solids	P, G	100	Refrigerate	7 d/7-14 d
Temperature	P, G	1,000	Analyze immediately	Analyze immediately

\* See text for additional details. For determinations not listed, use glass or plastic containers; preferably refrigerate during storage and analyze as soon as possible. Refrigerate = storage at 4°C, in the dark. P = plastic (polyethylene or equivalent); G= glass; G(A) or P(A) = rinsed with 1+1 HNO<sub>3</sub>; G(B) = glass, borosilicate; G(S) = glass, rinsed with organic solvents.

#### 4.4 SAMPLING POINTS AND ANALYTICAL SCHEDULE

Table 4.3 presents the suggested sampling points at the Shaw AFB WWTP. These points should be used consistently by all operators to help ensure the uniformity of all samples. Any change in sampling points or addition of sampling points must be communicated to all operators.

Table 4.4 presents a suggested sampling schedule for analyses run at the WWTP laboratory. This schedule can be adjusted as plant conditions dictate.

**TABLE 4.3**  
**SHAW AFB WASTEWATER TREATMENT PLANT**  
**SUGGESTED SAMPLING POINTS**

Sample Type	Sample Point
Plant Influent	At plant headworks between grit chamber and Parshall flume
Plant Effluent	At effluent metering chamber
Aeration Tanks	Discharge of basins
Tertiary Filter Effluent	Discharge of tertiary filters
Return Activated Sludge	Discharge of RAS Telescopic valves
Secondary Clarifiers	At discharge of clarifiers
Aerobic Digester	From middle of tanks with aeration in progress
Outfall	At the plant outfall

**TABLE 4.4**  
**RECOMMENDED ANALYTICAL SCHEDULE**

Sample	MON	TUES	WED	THUR	FRI	SAT	SUN
Influent pH	G	G	G	G	G	G	G
Influent BOD	--	--	C	--	C	--	--
Final Effluent BOD	--	--	C	--	C	--	--
Influent TSS	C	C	C	C	C	C	C
Secondary Clarifier TSS	C	C	C	C	C	C	C
Aeration MLSS	G	G	G	G	G	G	G
Aeration MLVSS	G	G	G	G	G	G	G
Return Sludge MLSS	C	C	C	C	C	C	C
Final Effluent TSS	C	C	C	C	C	C	C
Aeration Settleable Solids	G	G	G	G	G	G	G
Effluent Ammonia-Nitrogen	G	--	--	G	--	--	--
Aeration DO	G	G	G	G	G	G	G
Outfall DO	G	--	--	G	--	--	--
Outfall pH	G	--	--	G	--	--	--
Digester Total Solids	G	--	--	--	--	--	--
Digester Volatile Solids	G	--	--	--	--	--	--
Influent Temperature	G	G	G	G	G	G	G
Outfall Temperature	G	G	G	G	G	G	G
Effluent pH	G	G	G	G	G	G	G
Effluent Chlorine Residual	G	--	--	G	--	--	--
Outfall Chlorine Residual	G	--	--	G	--	--	--
Effluent Fecal Coliform	G	G	G	G	G	G	G
Tertiary Filter Effluent							
Total Phenols <sup>(q)</sup>	G	G	G	G	G	G	G

NOTE:

1. Sample Type: C = Composite, G = Grab
2. Drying Bed Sludge Analyses are performed on an as-needed basis.
  - (a) Monthly
  - (q) Quarterly

## CHAPTER 5

### LABORATORY TESTING

#### 5.1 INTRODUCTION

Analytical testing conducted for the Shaw AFB WWTP will generally be conducted by an outside contract laboratory for most NPDES permit parameters. Some parameters, such as pH and Total Residual Chlorine, will be done at the WWTP. The South Carolina Department of Health and Environmental Control (DHEC) has in place a strict laboratory certification program that incorporates criteria for labs and the analyst in the attainment of state certification. The certification is applicable only if a designated person is performing the required tests at a specific laboratory. Because laboratory staffing at Shaw AFB is limited to one person, it is imperative that the services of an outside certified lab be utilized for permit required analyses.

However, it is necessary for all operators to have a general knowledge concerning the analytical procedures used at the plant. Such knowledge will allow the operators to evaluate the laboratory data and make determinations as to the validity of the data and will provide the operators with a better understanding of the data collected and allow them to make more effective use of this data. By relating meaningful lab results to daily operation, the operator can effectively make process decisions, determine the efficiency of the process, predict and prevent problems that are developing, and determine causes of plant upsets.

The standard text used by most wastewater labs is entitled *Standard Methods for the Examination of Water and Wastewater*. This text must be followed explicitly for results to be acceptable to regulatory agencies. Some operators find it difficult to understand and to follow *Standard Methods*. This chapter is not to be considered as a substitute to *Standard Methods* but as a simplified guide for use by the Shaw AFB operations staff. As operators master these techniques, they should refer to *Standard Methods* to become aware of the possible pitfalls and interferences associated with these methods. This

chapter deals primarily with the laboratory analyses to be performed at the Shaw AFB wastewater treatment plant laboratory.

Other references to be consulted by the treatment plant operators for information concerning laboratory analyses include:

- *Methods for Chemical Analysis of Water and Wastes*, EPA.
- *Simplified Laboratory Procedures for Wastewater Examination*, Water Pollution Control Federation Publication No. 18.
- *Operation of Wastewater Treatment Plants*, Volume II, Sacramento State University.
- *Hach Handbook of Water Analysis*, Hach Chemical Company, 1979.

## 5.2 BIOCHEMICAL OXYGEN DEMAND ANALYSIS

### 5.2.1 Scope and Application

- 5.2.1.1 This method is applicable to the measurement of biochemical oxygen demand (BOD) in drinking, surface and saline waters, domestic and industrial wastes.
- 5.2.1.2 Concentrations of BOD from 2 up to about 8 mg/l may be measured directly. Multiplication by applicable dilution factors extends the range.
- 5.2.1.3 The effluent BOD from the Shaw AFB WWTP is limited by NPDES Permit. The permit requires a specified frequency of analysis for BOD.

### 5.2.2 Methodology

#### 5.2.2.1 Specific Method Utilized

This method was developed as a sequential, step-by-step procedure and is derived directly from Method 5210-B, p. 5-2 of *Standard Methods For The Examination of Water and Wastewater*, 18th Edition; 1992.

#### 5.2.2.2 Summary of Method

The method consists of filling with sample, to overflowing, an airtight bottle and incubating it at constant temperature for 5 days. Dissolved oxygen is measured initially and after incubation, and the BOD is computed from the difference between initial and final DO.

### 5.2.3 Sample Pretreatment

#### 5.2.3.1 Temperature Adjustments

1. Cold samples must be warmed slowly to room temperature,  $20.0 \pm 1.0^{\circ}\text{C}$ , before making dilutions.
2. Warm samples must be cooled slowly to room temperature,  $20.0 \pm 1.0^{\circ}\text{C}$ , before making dilutions.

#### 5.2.3.2 Check for $\text{Cl}_2$ Residual

1. Effluent samples must be free of chlorine residual.
2. Check the effluent samples for  $\text{Cl}_2$  residual using the Hach DR100 Colorimeter instrument. Use other operating and quality assurance

procedures that are provided in the Instrument Calibration Logs/Instructions book to calibrate and operate the DR100.

#### **5.2.3.3 Adjustment of Sample pH**

1. Sample pHs must be within the 6.5 - 7.5 range for the BOD test.
2. Analyze the samples on the pH meter. Those samples having a low pH (acidic) must be adjusted to the aforementioned pH range using sodium hydroxide solution. Those samples having a high pH (alkaline) must be adjusted to the same range using sulfuric acid solution. The solutions must be of such strength that the sample is not diluted by more than 0.5 percent.
3. Calibrate the pH meter using the Instrument Calibration Logs/Instructions book. Refer to this book for instructions on how to perform a pH test.
4. Raise or lower the pH of the samples by the dropwise addition of sodium hydroxide or sulfuric acid solutions while the sample is stirring and being monitored by the pH meter and probe.

#### **5.2.4 Sample Dechlorination**

##### **5.2.4.1 Determination of the Amount of Sodium Sulfite Solution Needed to Dechlorinate Samples**

1. Measure 100 ml of chlorinated sample in a 100-ml graduated cylinder and pour it into a 500-ml Erlenmeyer flask. (This procedure only need be performed if the effluent samples contain  $\text{Cl}_2$  residual.)
2. Using a 10-ml serological pipette, measure 10 ml of 1 + 50 sulfuric acid solution. Transfer into the Erlenmeyer flask and swirl to mix.
3. Using a 10-ml serological pipette, measure 10 ml of 10% potassium iodide solution. Transfer into the Erlenmeyer flask and swirl to mix. The solution will turn a red-brown color.
4. Fill a 25-ml buret with 0.025N sodium sulfite solution. Bleed the air out of the stopcock and refill to the 0.0 ml line.
5. Place the Erlenmeyer flask on a magnetic stir plate, add a magnetic stir bar, and titrate the sodium sulfite at a fast dropwise rate while stirring. When

the red-brown color changes to one of a pale yellow, stop the addition of sodium sulfite solution.

6. Squirt approximately 2 ml of starch indicator solution into the flask. The color of the contents should turn to a pale or medium blue color.
7. Continue the addition of sodium sulfite from the buret at a dropwise rate of about 1 drop/second.
8. When the solution turns from blue to colorless, immediately stop the addition of sodium sulfite.
9. Record the ml of sodium sulfite used to one place to the right of the decimal point.
10. Discard the 100-ml sample in the Erlenmeyer flask.
11. Calculate the amount of 0.025N sodium sulfite needed to dechlorinate the entire BOD sample by following the example calculation below.

**EXAMPLE CALCULATION:**

3.2 ml of 0.025N sodium sulfite was used in the titration of the 100 ml sample and the entire BOD sample volume is 1 liter (1000 ml).

$$\frac{1000 \text{ ml (ml of entire comp.)}}{100 \text{ ml (amt. used for titration)}} \times \frac{3.2 \text{ ml (ml of 0.025N Na}_2\text{SO}_3)}{1} = 32 \text{ ml}$$

32 ml of  $\text{Na}_2\text{SO}_3$  is needed to dechlorinate the remaining or entire BOD composite sample.

12. Using a serological pipette, or a graduated cylinder if the amount calculated is greater than 10 ml, transfer the calculated amount of  $\text{Na}_2\text{SO}_3$  to the BOD composite sample, and shake to mix the contents.
13. The sample must stand for 20 minutes to allow for the dechlorinating action of the  $\text{Na}_2\text{SO}_3$ .
14. Repeat Steps 1-3 to ensure the dechlorination has taken place. The solution color should be colorless if all  $\text{Cl}_2$  has been removed. If the solution is pale blue, there is still  $\text{Cl}_2$  present and Step 15 should be performed.

15. Add 2 drops of the 0.025N  $\text{Na}_2\text{SO}_3$  and mix if the solution changes to a pale blue. Proceed to step 16.
16. Repeat Steps 1-3 and 15 until the solution remains colorless, then discard the titration sample.

## 5.2.5 Laboratory Pure Water

### 5.2.5.1 Distilled Water Preparation

1. Distill 3-6 liters of water (quantity used in the BOD test depends upon the number of BOD bottles that will be set up. Check pH,  $\text{Cl}_2$  residual, and megohms upon cooling. pH should be 5.5-7.5, conductivity should be greater than 0.2 megohm as resistivity or less than 5.0 micromhos/cm at 25° C, and free chlorine should be 0.0.
2. Store the water in a large, small-necked jug with a dispensing spout on the bottom. Plug the jug with a piece of loose fitting cotton.
3. Place the water-filled jug in the BOD incubator at 20°C for 24 hours prior to the BOD test.
4. Store another portion of distilled water in a smaller, small-necked jug. Plug the jug with a piece of loose-fitting cotton. This will be used for a seed solution.
5. Store the seed water jug in the BOD incubator at 20°C for 24 hours prior to the BOD test.

### 5.2.5.2 BOD Dilution Water

1. Remove the large jug containing distilled water just before the BOD dilutions are ready to be made.
2. Empty the contents of one of the Hach BOD Nutrient Buffer Pillows (for preparation of either 3 or 6 liters -- which one depends upon the volume of the distilled water in the jug and/or the amount of the volume of dilution water required to fulfill all the dilution amounts of the BOD bottles that will be set up) into the large jug, stopper the jug, and shake vigorously for 1 minute to dissolve and mix the contents of the pillow into the water.

## 5.2.6 Polyseed Innoculum -- Seed

### 5.2.6.1 Needed Items

1. Small jug of aerated distilled water at 20°C.
2. One Polyseed capsule.
3. Two Hach, BOD Nutrient Buffer Pillows for Preparation of 300 ml.
4. 500 ml graduated cylinder.
5. 1000 ml beaker.
6. Magnetic stir plate and bar.

### 5.2.6.2 Procedure

1. Measure 600 ml of the aerated distilled water using the 500-ml graduated cylinder and pour it into the 1000-ml beaker.
2. Add the contents of the BOD Nutrient Buffer Pillows to the water in the beaker.
3. Mix the buffer solution using the magnetic stir bar and the magnetic stir plate.
4. Pour off 100 ml of the nutrient buffer solution and discard it. (This solution may be saved if it will be needed to dilute a very strong sample such as an influent.)
5. Open a BOD Polyseed capsule and empty the contents into the beaker of nutrient buffer solution. (Be vary careful not to inhale dust from the Polyseed capsule--it will cause serious respiratory problems. Wash hands after handling.)
6. Place the seed solution on the magnetic stir plate and stir. This seed solution must be stirred throughout the entire BOD set up procedure to keep the bacteria in suspension. The seed solution cannot be used for 1 hour prior to its addition to the BOD bottles. It should not be used after 6 hours from the time its prepared.

## 5.2.7 BOD Procedure

### 5.2.7.1 Needed Items

1. BOD bottles in their racks.
2. Pipettes, assorted volumes and types.
3. Graduated cylinders, assorted volumes.
4. Shallow pan (for catching probe rinse water).
5. Wash bottle filled with distilled water.
6. DO probe, meter, and their calibration instructions.
7. BOD bench sheet (filled out beforehand containing: % dilutions of specific samples, ml seed used, seed controls, standard solutions, laboratory ID numbers, dates, times, and analysts initials.) An example bench sheet is included in Appendix A.

### 5.2.7.2 Set Up

1. Calibrate the meter and DO probe to give it 15 minutes warm-up time. See Section 5.2.9.
2. Fill the three bottles reserved for dilution water blanks all the way with dilution water from the large dispenser jug.
3. Fill all other bottles full enough to allow some space for other solutions that will need to be added such as: seed control solution, influent and effluent samples, standard solutions, and seed for the samples that require it.
4. Add the required ml of samples and standards to produce the desired concentrations. (To find the ml of sample needed to produce a 20% dilution, multiply 20 by 3 (it's a 300-ml bottle) and you will get 60. The amount of effluent sample needed for that bottle is 60 ml.)
5. To prepare a 2% glucose-glutamic acid standard solution, obtain one Hach Glucose-glutamic Acid BOD Standard Solution Voluette. Shake the voluette vigorously, snap off the neck, and promptly remove 3.0 ml using a volumetric pipette. Transfer the solution to a bottle filled 3/4 full with dilution water.

6. Swirl the contents of the voluette and remove another portion using the 3.0-ml volumetric pipette. Transfer the solution to another bottle filled 3/4 full with dilution water.
7. Repeat Step 6 for the remaining bottle.

\*NOTE\* This standard is a check to ensure the activeness of the seed used and the purity of the distilled water. A standard check should be performed for approximately every tenth sample run. If the 5-day BOD value of the standard check solution is outside of a  $200 \pm 37$  mg/l range, reject any BOD results made with the seed and dilution water, and find the cause of the problem.

8. Using a 50-ml graduated cylinder, measure the appropriate amount of seed solution required for each of the three seed control bottles, and pour into the respective bottles. The amount of seed solution used in the control bottles depends on the calculated seed correction factor. The calculated seed correction factor must be within a range of 0.6-1.0 mg/l; therefore, the amount (ml) of seed control solution used must produce a calculated seed correction within this range.
9. Using a wide-tipped, 10-ml serological pipette, transfer 4.0 ml of seed solution to each of the bottles that need seed. Examples of samples needing seed are: untreated industrial wastes, disinfected wastes, high temperature wastes, or wastes that have extremely high pH values.
10. Finish the last part of the DO meter calibration.

\*NOTE\* This next part of the BOD procedures has to be completed within 15 minutes from the time you add seed to the samples, because the microbial activity will quickly deplete the O<sub>2</sub> in the bottles and a true initial DO will not be obtained.

#### 5.2.7.3 Initial DO Readings

1. Insert the stirring boot of the DO electrode into the first blank dilution water bottle. Slip the DO electrode into the stirring boot. Place on the magnetic stirrer and stir. Wait for the meter to stabilize and record the DO concentration (in mg/l) in the space provided on the BOD bench sheet.

2. Stopper, water seal, and cap the bottle.
3. Record the DO that was obtained for the first bottle of blank dilution water for the remaining two bottles of blank dilution water. Stopper, water seal, and cap the bottles as soon as the DO determinations are completed.
4. Read and record the DO for each of the remaining sample bottles using the same method as stated in Step 1 above.
5. Stopper, water seal, and cap the bottles as you find the DO concentration of each.

\*NOTE\* The DO electrode and stirring boot must be thoroughly rinsed with distilled water after each bottle's initial DO concentration is determined so that there will not be any carryover of contaminates from bottle to bottle.

6. Place the rack(s) of bottles into the BOD incubator, leave them there undisturbed, for 5 days at  $20.0^{\circ}\pm 1.0^{\circ}\text{C}$ .

## 5.2.8 Obtaining Results

### 5.2.8.1 Final DO Readings

1. Read and record the DO of all bottles after the 5-day incubation period using the methods described in Step 1 of Section 5.2.7.3, "Initial DO Readings." There is no need to rinse the electrode and stirring boot between sample readings in this part of the procedure.
2. Record the final DO results in their respective places on the BOD bench sheet.
3. Subtract the 5-day final DO readings from the initial DO readings.

\*NOTE\* If the depletion of all three dilution water blanks is greater than 0.2 mg/L, the test results must be discarded. In this case, the method of washing labware may be inadequate, or the distilled water used may be of a poor quality. Ensure that the problem(s) is/are corrected.

#### **5.2.8.2 Calculating Seed Factor**

1. Once the depletions of the three seed control bottles are obtained (Initial DO - Final DO), a seed factor can be calculated. Divide each depletion by the % concentration of each of the respective bottles.
2. Using only those seed control bottles that gave a depletion of at least 2 mg/l and a residual of at least 1 mg/l DO, figure the seed factor by averaging those that meet the criteria. Do this by taking each depletion times the amount of seed added to those seeded samples (i.e., 4.0 ml) and divide by the % concentration of that seed control bottle. Write the answers on the bench sheet under the seed factor column and average them.
3. Write the obtained (average) seed factor on the bench sheet in the seed factor spaces for each of the sample bottles that had seed added to them.

#### **5.2.8.3 Finding Final Depletion**

1. Find the final depletion of those bottles containing seeded samples by subtracting the average seed factor from each depletion.
2. The final depletion of those bottles containing unseeded samples is found by simply using the depletion amount; carry those same amounts to the final depletion spaces.

#### **5.2.8.4 Finding BOD, mg/l and Average BOD, mg/l**

1. Take each final depletion and divide by % concentration (% concentration in its decimal form).
2. Average the BOD, mg/l using only those samples that have a depletion of at least 2 mg/l with at least 1 mg/l remaining. The final depletion after 5 days must be within the recommended 40-70 percent range. (Final Depletion/Initial DO X 100 = recommended depletion range percentage.)

#### **5.2.9 Calibration of Dissolved Oxygen Electrode**

- 5.2.9.1** The dissolved oxygen probe should be calibrated each day that it is used. At the end of a series of dissolved oxygen measurements, the calibration should be checked to ensure that it has been maintained within 0.2 mg/l.

1. Using a soft tissue, carefully blot all water droplets from the electrode and membrane. Insert the electrode in a BOD bottle.
2. Connect the Model 97-08 DO Electrode to the Orion SA 520 Meter.
3. Leave the electrode mode switch "off," and do not use the ATC probe.
4. Set the mode switch of the Model SA 520 Meter to TEMP and scroll in 25.0°C; press ENTER.
5. Set the mode switch to pH 0.01.
6. Press the SLOPE key. Scroll in 100.0 and press ENTER.
7. Press ISO. Scroll in 7.00 and press ENTER.
8. Press CAL. Wait for the "1" to disappear and scroll in 7.00. Press ENTER.
9. Wait for the "2" to disappear and press SAMPLE.
10. Turn the mode switch on the electrode to BT CK. A good battery is indicated by a reading of 13.00 or greater.
11. Turn the mode switch on the electrode to ZERO. Use the zero calibration control knob on the electrode to set the meter to read 0.00.
12. Insert the reservoir (funnel) into a BOD bottle containing enough distilled water to just cover the bottom of the bottle. Insert the electrode, making sure the electrode does not have water droplets clinging to the outside of the membrane and that the top of the electrode is not immersed on the water.
13. Let stand for 30 minutes to ensure water saturation of air in the BOD bottle. This bottle is used for electrode storage between measurements.
14. Turn the electrode mode switch to the AIR position. Use the air calibration control knob to set the meter to read 7.60.
15. Turn the electrode mode switch to H<sub>2</sub>O for sample analysis.
16. When analysis is completed, turn off the electrode, clean it, and store it in the BOD bottle.

NOTE: If the electrode mode switch is left in any position other than "OFF," the batteries in the electrode will die. Ensure that the electrode is turned off after each use.

## 5.3 TOTAL SUSPENDED SOLIDS ANALYSES

### 5.3.1 Scope and Application

This method covers the determination of total suspended solids. Total suspended solids is a measure of the effectiveness and efficiency of many wastewater treatment processes and plants as a whole. The effluent total suspended solids from the Shaw AFB WWTP is limited by the NPDES Permit. The NPDES Permit requires a specified frequency of analysis for total suspended solids. Suspended solids encompass the portion of total solids retained after filtration.

### 5.3.2 Methodology

#### 5.3.2.1 Specific Method Utilized

This method was developed as a sequential, step-by-step procedure and is derived directly from Method 2540 D, p. 2-56 of *Standard Methods For The Examination of Water and Wastewater*, 18th Edition; 1992.

#### 5.3.2.2 Summary of Method

A well-mixed sample is filtered through a weighed, standard, glass-fibered filter, and the residue retained on the filter is dried to a constant weight at 103-105°C. The increase in weight of the filter represents the total suspended solids.

### 5.3.3 Interferences:

- 5.3.1.1 Large floating or submerged agglomerates of nonhomogeneous materials in the sample should be excluded if it is determined that their inclusion is not desired in the final result.
- 5.3.1.2 Limit the sample size to yield no more than 200 mg of residue, because the excessive residue may form a water entrapping crust.
- 5.3.1.3 For those samples that contain great amounts of dissolved solids, thoroughly rinse the filter to remove the dissolved material.
- 5.3.1.4 Weighing boats (pans) should always be handled with forceps; the grease off of fingertips will throw the results off, thus producing a higher, false weight.

### **5.3.4 Apparatus and Materials**

#### **5.3.4.1 Apparatus**

1. Vacuum pump
2. Filtering flask and vacuum tubing
3. Filter funnel assembly
4. Desiccator with dry desiccant
5. Analytical balance, capable of weighing to 0.1 mg.
6. Rinse bottle containing distilled water
7. Forceps
8. Drying oven
9. TSS Bench Sheet (see Appendix A)
10. Graduated cylinder

#### **5.3.4.2 Materials**

1. Aluminum weighing boats (pans)
2. 47 mm glass fiber filters (Whatman 934AH; Gelman A/E; Millipore 4. AP40; or equivalent)
3. Pen

### **5.3.5 Procedure**

#### **5.3.5.1 Preparation of the Glass Fiber Filter**

1. Place the glass fiber filter on the base of the filter funnel assembly with the wrinkled side upward. Use forceps to handle the filter. Note: Filters and weighing boats must be handled throughout this entire procedure with forceps.
2. Apply vacuum to the flask using the vacuum pump and tubing. Wash the entire surface area of the filter using three 20-ml portions of distilled water. Continue the suction for 2 minutes to remove all traces of water.
3. Cut off the vacuum and remove the filter. Place the filter in a numbered, aluminum weighing boat.
4. Repeat Steps 1-3 for the remaining filters.
5. Place the weighing boats and filters in the drying oven at a temperature of 103-105°C for one hour.

6. Remove the weighing boats and filters from the oven, and place in the sealed desiccator. Allow the filters to cool for 30 minutes.
7. Using the analytical balance, weigh and record the weights of each weighing boat and filter.
8. Repeat Steps 5-7 (as many times as it takes) to obtain a constant weight, or until the weight loss is less than 0.5 mg between successive weighings.

#### 5.3.5.2 Sample Analysis

1. Remove the glass fiber filter from the weighing boat, using forceps, and place it on the base of the filter funnel assembly that is contained in the filtering flask. Ensure the filter is placed on the filter funnel assembly's base with the wrinkled side up.
2. Place the filtering funnel upon the filter and base of the filtering funnel.
3. Apply vacuum to the flask and filter a well-mixed, measured volume of sample through the filter. Record the volume of sample filtered on the bench sheet. Continue to apply suction for 2 minutes to ensure all traces of water are removed. Note: Cleaner samples, such as effluents, should be filtered before dirtier samples.
4. Rinse the measuring devise (graduate cylinder) with approximately three 20-ml portions of distilled water, and pour the rinsings into the filtration unit. Using the wash bottle, rinse the entire wall area of the filtering funnel thoroughly. Note: Allow complete drainage between rinsings.
5. Apply suction for an additional 2 minutes to ensure all traces of water are removed.
6. Remove the filter from the unit, using forceps, and place into the weighting boat.
7. Repeat Steps 5-7 as described in Section 5.3.5.1, "Preparation of the Glass Fiber Filter," until a constant weight is obtained, or until the weight loss is less than 4 percent of the previous weight (0.5 mg, whichever is less).

### 5.3.5.3 Calculating Total Suspended Solids, mg/l

$$\text{TSS mg/l} = \frac{\text{A} - \text{B} \times 1,000,000}{\text{Sample Volume, ml}}$$

Where: A = Weight of the filter and weighing boat + dried residue, g.

and

B = Weight of the filter and weighing boat, g.

## 5.4 FECAL COLIFORM MEMBRANE FILTER PROCEDURE

### 5.4.1 Scope and Application

This method covers the determination of fecal coliform bacteria density. Fecal coliform bacteria are an indicator organism that provides a measure of the effectiveness of the disinfection process of wastewater treatment plant.

### 5.4.2 Methodology

#### 5.4.2.1 Specific Method Utilized

This method was developed as a sequential, step-by-step procedure and is derived directly from Method 9222D, P9-60 of *Standard Methods for the Examination of Water and Wastewater*, 18th Ed., 1992.

#### 5.4.2.2 Summary of Method

The Membrane Filter (MF) Coliform Method is a fast, simple way of estimating bacterial populations in water. A well-mixed sample volume is passed through a membrane filter with a pore size small enough (0.45 microns) to retain the bacteria present. The filter is placed on an absorbent pad (in a petri dish) saturated with a culture medium that is selective for coliform growth. The petri dish containing the filter and pad is incubated, upside down, for 24 hours at  $44.5^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$ . After incubation, the colonies that have grown are identified and counted by using a low-power microscope.

### 5.4.3 Supporting Materials and Equipment

#### 5.4.3.1 Apparatus and Materials

1. Clippers, large
2. Graduated cylinders, 100 ml
3. Petri dishes, sterile
4. Filter holder
5. Filter pump
6. Membrane filters, pre-sterilized in lab autoclave or commercially available
7. Filter flask, 500 ml
8. Forceps, flat-end, 110 mm

9. Pads, sterile, commercially available or pre-sterilized in lab autoclave
10. Pipettes, sterile, 10 ml
11. Tubing, rubber
12. Incubator - water bath or heat sink  $44.5 \pm 0.2^{\circ}\text{C}$
13. Microscope, 10x - 15x magnification

#### **5.4.3.2 Reagents**

1. Dechlorinating Reagent Powder Pillows or 10% Solution of Sodium Thiosulfate.
2. M-FC Medium, commercially prepared
3. 70% Isopropyl Alcohol
4. Phosphate buffer solution

#### **5.4.4 Analytical Procedures**

##### **5.4.4.1 Sterilization of Equipment**

1. Before starting the test, preheat the autoclave to  $121^{\circ}\text{C}$ , and wash all sample bottles, graduated cylinders and containers, forceps, filter flasks, and filter holder in hot, soapy water. Rinse several times with tap water, then with demineralized water, and dry thoroughly. Prior to sterilization, prepare items as follows, then sterilize in an autoclave at  $121^{\circ}\text{C}$  for 15 minutes.
2. Sample bottles should be capped and covered with brown Kraft paper.
3. Forceps should be wrapped in brown paper and sealed with masking tape.
4. The opening of the graduated cylinder and the filter flask should be covered with metal foil or brown paper.
5. The two parts of the filter should be wrapped separately in brown paper and sealed with masking tape.

##### **5.4.4.2 Preparation of Phosphate Buffer Solution**

1. Phosphate Buffer. The phosphate buffer is used to dilute and rinse samples. This solution must be sterile, because any organisms present in the buffer may interfere with coliform counts. Prepare the buffer by:

2. Stock Solution I. Dissolve 34.0 grams of potassium dihydrogen phosphate ( $\text{KH}_2\text{PO}_4$ ) in 500 ml of laboratory pure water. Adjust the pH to 7.2 with 1 N NaOH. Dilute to 1000 ml with laboratory pure water to produce 1 L of stock buffer solution. Refrigerate stock buffer. Discard it if it becomes turbid.
3. Stock Solution II. Dissolve 28 grams of magnesium chloride ( $\text{MgCl}_2$ ) or 81.4 gram of  $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$  in 1 L of laboratory pure water.
4. Working Solution. Add together 1.35 ml of Stock Solution I and 5.0 ml of Stock Solution II and dilute to 1 L with laboratory pure water in an aspirator bottle. Mix completely.

#### **5.4.4.3 Equipment and Material Preparation**

1. Prior to preparing the sample set-ups, wipe down the countertop being used with isopropyl alcohol.
2. Set out petri dish for each sample to be tested. Put sterile pad into each dish.
3. Prior to opening, dip the etched end of a M-FC Medium Ampoule in 70% isopropanol alcohol for 1 minute. Allow the alcohol to evaporate.
4. Snap open the neck of the ampoule, being careful not to touch the area surrounding the etched mark.
5. Pour the M-FC Medium evenly over the absorbent pad in the petri dish.
6. Unwrap the forceps, filter holder, filter flask, and graduated cylinder.
7. Attach the rubber tubing to the filter pump and place the bottom half of the filter holder in the neck of the filter flask.
8. Dip the end of the forceps in 70% isopropyl alcohol for one minute.
9. Open a package of sterile membranes. Using the sterile forceps, carefully center a sterile filter on the porous plate of the filter apparatus. Be sure the grid side is up.
10. Carefully put the top half of the filter holder in place over the filter, and clamp the holder together.

#### 5.4.4.4 Sample Preparation and Filtration

1. Collect at least 250 ml of water from a representative effluent site. Sample containers should be wide-mouth glass or polypropylene bottles that have been carefully cleaned and rinsed with demineralized water, then sterilized in the autoclave. To avoid contamination during sampling, do not handle the stopper or neck of the sample bottle. Keep container closed until ready to use, then fill without rinsing and replace the cap immediately. Be sure to leave at least 1 inch of head space above the sample in the container. For chlorinated samples, add the contents of one Dechlorinating Reagent Pillow or 0.2 ml of a 10% solution of Sodium Thiosulfate to each sample bottle to counter any residual chlorine that may be present prior to sterilizing in the autoclave.
2. Shake the sample bottles to distribute the bacteria evenly, then measure the sample into the sterile graduated cylinder. Add a small volume of sterile buffer dilution water to filter funnel and graduated cylinder.
3. Prepare a minimum of three dilutions. Dilutions of 10% (10 ml), 1% (1 ml) and 0.1% (0.1 ml) should be used initially. If necessary, dilutions should be adjusted to obtain membrane filter counts between 20 and 60 colonies. A sterile buffer dilution water blank should be prepared first, then the smallest dilution next, and so forth (weakest to strongest). A known positive sample should be set up last to test for the viability of the test.
4. Pour the sample into filter holder, turn on vacuum and filter. Rinse the filter holder with three 20- to 30-ml portions of sterile buffer dilution water. Allow to vacuum. Turn off the pump.
5. Dip forceps in 70% isopropyl alcohol for 1 minute, then air dry. Remove the filter holder and immediately peel off the filter with sterile forceps. Place the filter on the absorbent pad. Avoid entrapping air under the filter when placing it on the absorbent pad.
6. Replace cover on petri dish and label. Inspect membrane filter after 20 seconds to insure even coloration. Place the petri dishes in the incubator in an inverted position and incubate for 22 to 24 hours at  $44.5^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$ .

#### **5.4.4.5 Counting Membrane Filter Colonies**

Membrane filter colonies are best counted with a magnification of 10 to 15 diameters and the light source adjusted to give maximum sheen. A binocular wide field dissecting microscope is recommended as the best optical system. However, a small fluorescent lamp with magnifier is acceptable. Colony differentiation is best made with white fluorescent light.

#### **5.4.4.6 Calculation of Coliform Density**

Report the coliform density in terms of coliforms/100 ml. Compute the count, using membrane filters with 20-60 coliform colonies per membrane, by the following equation:

$$\text{Coliform colonies/100 ml} = \frac{\text{Coliform Colonies counted}}{\text{ml Sample Filtered}} \times 100$$

## 5.5 pH ANALYSES

### 5.5.1 Scope and Application

This method covers the determination of pH in aqueous samples and is applicable to drinking, surface, and saline waters, domestic and industrial wastes. The effluent pH from the Shaw AFB WWTP is limited by the NPDES Permit. The NPDES Permit requires a specified frequency of analysis for pH.

### 5.5.2 Methodology

#### 5.5.2.1 Specific Method Utilized

This method was developed as a sequential, step-by-step procedure and is derived directly from Method 4500-H, p. 4-65 of *Standard Methods For The Examination of Water and Wastewater*, 18th Edition; 1992, and *Method E150.1, Methods for Chemical Analysis of Water and Wastes*, EPA-600/4-79-020, March 1983.

#### 5.5.2.2 Summary of Method

A well-mixed sample is poured into a beaker with a magnetic stir bar. A pH probe is lowered into the sample, and the pH and temperature are read and recorded.

### 5.5.3 Two Buffer Calibrations

#### 5.5.3.1 Introduction

1. Use two buffers that will bracket the expected pH of the sample that is being analyzed.
2. Buffers must never be reused. Change the buffers with each calibration.
3. All buffers and samples must be stirred when calibrating the meter or when analyzing samples.
4. The pH electrode must be stored in electrode storage solution or pH 7 buffer when it is not being used.
5. The Orion electrode, 9104BN must be kept filled with 4M KC1 saturated with AgCl1.
6. The electrode filling hole must be uncovered when in use and covered when not in use using the filling hole slip cover.

7. The electrode should be inspected weekly for scratches, cracks, salt crystal buildup, or membrane/junction deposits.
8. Drain the electrode reference chamber, flush it with fresh filling solution, and refill the chamber on a weekly basis. See the electrode manual for general exterior cleaning and removal of membrane/junction deposits.

#### **5.5.3.2 Calibration of pH Meter**

1. Connect the pH electrode and the automatic temperature compensator (ATC) probe to the meter. Ensure that the meter is plugged into a power outlet or that the meter is equipped with good batteries.
2. Select the pH resolution and mode by sliding the mode switch to pH 0.01 or 0.1.
3. Remove the electrode and ATC probe from the storage solution. Rinse with distilled water and blot dry. Place them in to the lower buffer. Drop a small magnetic stirring bar into the buffer and turn on the magnetic stirring place.
4. Press ISO and verify that the display is 7.00. Press Enter. Log the ISO value into the calibration book.
5. Press CAL. The display will alternate between .1. and the pH value of the buffer. The .1. indicates that this is the first buffer and a value has not been entered.
6. Wait for the display to stabilize and press Enter. The display will freeze for 3 seconds, then it will advance to .2., indicating that the meter is ready for the second buffer.
7. Log the entered pH buffer value into the calibration book.
8. Remove the electrode and ATC probe from the buffer, rinse, and blot dry.
9. Place the electrode and ATC probe into the higher value buffer. The display will alternate between .2. and the pH value of the buffer.
10. Wait for the pH value to stabilize and press Enter. The pH of the second buffer will be displayed after entering. Record this entered pH value in the calibration book.

11. Press Slope. A properly functioning and calibrated meter should display a slope around 92-102%. Log the slope value into the calibration book.
12. Press Sample.
13. Slide the mode switch to Temp. Log the temperature into the calibration book.
14. Slide the mode switch back down to the desired pH resolution (pH 0.01 or 0.1).
15. Remove the electrode and ATC probe from the second buffer, rinse, and blot dry.
16. Place the electrode and ATC probe into a fresh, lower pH value buffer.
17. Wait for the display to stabilize and record the pH value of the buffer into the calibration log book. This step is performed to check the calibration of the meter; since this buffer has a known pH value, the meter should display the pH of this buffer  $\pm 0.02$  s.u.
18. Remove the electrode and ATC probe from the check buffer, rinse, and blot dry.  
The meter is now ready for sample measurements.

#### 5.5.3.3 Sample Measurements

1. Place the electrode and ATC probe into an aliquot of sample that has an unknown pH. Drop in a magnetic stirring bar and turn on the magnetic stirring plate.
2. Wait for the meter to display a stable pH value. Record the stable value/pH of the sample.
3. Remove the electrode and ATC probe from the sample, rinse, and blot dry.
4. Place the electrode and ATC probe into the electrode storage solution.
5. Cover the electrode filling solution hole with the slip cover if the meter is not to be used again that day. Also, turn the meter off if it is not going to be used again that day. If the meter is used again after 2 hours from the last calibration, recalibrate it. A one-buffer calibration may be performed in this instance. If the meter has been turned off, a two-buffer calibration must be performed.

## 5.5.4 One-Buffer Auto Calibration

### 5.5.4.1 Introduction

1. A one-buffer calibration may be performed on the meter only if the meter has been calibrated earlier using two buffers and it has not been turned off.
2. The slope value obtained from the previous calibration using two buffers may be used to perform the one-buffer calibration, or a slope value of 100.0 may be scrolled in and entered.
3. A fresh buffer that has a pH value nearest the expected pH of the sample should be used to calibrate the meter.

### 5.5.4.2 Calibration

1. Verify the slope value by pressing Slope. Enter the previous slope, as mentioned above in the introduction, or scroll in 100.0 and Enter.
2. Rinse the electrode and ATC probe and blot them dry.
3. Place the electrode and ATC probe into the chosen buffer.
4. Slide the mode switch to the desired resolution (0.01 or 0.1).
5. Press Cal. The display will alternate between .1. and the pH of the buffer, indicating this is the first buffer and a value has not been entered.
6. Wait for a stable pH display and press Enter.
7. The display will freeze for 3 seconds then advance to .2., indicating the meter is ready for the second buffer.
8. Instead of using a second buffer, press Sample. The letters pH will be displayed, indicating the meter is ready for sample measurements.

### 5.5.4.3 Sample Measurements

1. Remove the electrode and ATC probe from the buffer. Rinse and blot them dry.
2. Place the probes into the sample.
3. Wait for a stable display on the meter and record the value as the pH of the sample.
4. Remove the probes from the sample, rinse, and blot them dry.

5. Place the probes into the electrode storage solution. Cover the electrode filling hole with the slip cover and turn the meter off if it is not to be used again that day.

NOTE: The buffer and sample(s) must be stirred. Use a magnetic stirring bar and a magnetic stirring plate to facilitate. Also, rinse the probes with distilled water.

## 5.6 CHLORINE RESIDUAL - COLORIMETRIC METHOD

### 5.6.1 Scope and Application

- 5.6.1.1 This method is applicable to the measurement of total, free or combined residual chlorine in water or wastewater samples.
- 5.6.1.2 Concentrations of residual chlorine from 0 to 2.00 mg/l may be measured directly.
- 5.6.1.3 The total residual chlorine in the effluent from the Shaw AFB WWTP is limited by the NPDES Permit. The NPDES Permit requires a specific frequency of analysis for residual chlorine.

### 5.6.2 Methodology

#### 5.6.2.1 Specific Method Utilized

This method was developed as a sequential step-by-step procedure and is derived directly from Method 4500-C1G, page 4-45 of *Standard Methods For The Examination of Water and Wastewater*, 18th Edition; 1992.

#### 5.6.3 Summary of Method

Chlorine can be present in water as free available chlorine and as combined available chlorine. Both forms can exist in the same water and be determined together as the total available chlorine. Free chlorine is present as hypochlorous acid and/or hypochlorite ion. Combined chlorine exists as monochloramine, dichloramine, nitrogen trichloride, and other chloro derivatives. The combined chlorine oxidizes iodide in the reagent to iodine. The iodine reacts with DPD (N, N-diethyl-p-phenylenediamine) along with free chlorine present in the sample to form a red color which is proportional to the total chlorine concentration. To determine the concentration of combined chlorine, run a free chlorine test. Subtract the results from the results of the total chlorine test to obtain combined chlorine.

#### 5.6.4 Total Residual Chlorine

##### 5.6.4.1 Apparatus and Materials

1. 25-ml beaker
2. Sample cell holders

3. DR 2000 Spectrophotometer
4. DPD Total Chlorine Powder Pillows

#### **5.6.4.2 Procedure**

1. Enter the stored program. Press 80. Press Read/Enter.
2. Rotate the wavelength dial until the small display shows 530 nm.
3. Press Read/Enter. Display will show mg/l Cl<sub>2</sub>.
4. Fill sample cell with 25 ml of sample. Stop on white line.
5. Add the contents of one DPD Total Chlorine Powder Pillow to the sample cell. Stopper the sample cell and shake for 20 seconds. Remove stopper.
6. Press Shift Timer. A 3-minute reaction period will begin.
7. Timer will beep at the end of 3 minutes. Display will show mg/l Cl<sub>2</sub>. Fill another sample cell (the blank) with 25 ml of sample. Place it into the cell holder.
8. Press Zero. Display will show Wait, then 0.00 mg/l Cl<sub>2</sub>
9. Within 3 minutes, place the prepared sample into the cell holder. Close the light shield.
10. Press Read/Enter. The display will show WAIT, then the result in mg/l Chlorine will be displayed.

#### **5.6.5 Free Residual Chlorine**

##### **5.6.5.1 Procedure**

1. Enter the stored program number. Press 80. Press Read/Enter. The display will show Dial nm to 530.
2. Rotate the wavelength dial until the small display shows 530 nm.
3. Press Read/Enter. The display will show mg/l Cl<sub>2</sub>.
4. Fill a sample cell with 25 ml of sample. Place it into the cell holder.
5. Press Clear Zero. The display will show WAIT, then 0.00 mg/l Cl<sub>2</sub>.
6. Fill another cell with 25 ml of sample.

7. Add the contents of one DPD Free Chlorine Powder Pillow to the sample cell. Stopper the sample cell and shake for 20 seconds. Remove stopper.
8. Within 1 minute of reagent addition, place the prepared sample into the cell holder. Close the light shield.
9. Read Enter. The display will show WAIT, then mg/l Chlorine will be displayed.

### **5.6.6 Standard Additions for Analytical Accuracy Control**

#### **5.6.61 Introduction**

Standard additions is an accepted technique for checking the validity of test results. The technique, also known as spiking and known additions, can be used to check the performance of the reagents, the instrument, the apparatus, and the procedure.

#### **5.6.6.2 Apparatus**

1. 1 voluette ampule
2. 1/100 pipette
3. 100-ml volumetric flask
4. 25-ml graduated cylinder
5. 1 DPD free powder pillow (10 ml)
6. Distilled or deionized (DI) water

#### **5.6.6.3 Procedure**

1. Add 25 ml of DI water and one DPD Free Powder Pillow to graduated cylinder. Wait 3 minutes (not longer than 6)
2. Cover ampule with paper towel and snap open. Pipette 0.1 ml of Free chlorine Standard to the sample. Swirl to mix.
3. Read the mg/l Chlorine and record.
4. Repeat the addition of 0.1 ml of Free Chlorine Standard five times ensuring facility Chlorine results brackets standard curve.

NOTE: Each incremental addition adds 0.27 mg/l of Free Chlorine to the sample. If a less than or greater concentration value is added to sample, as a result of the additions, begin a systematic check to locate and correct the problem.

#### **5.6.6.4 Procedure for Curve**

1. Prepare five known concentrations with values covering the expected range. Record data.
2. mg/l Chlorine Standard (concentration) values are plotted on the horizontal scale. Meter (transmittance) value are on the vertical scale.
3. Values are plotted from bottom to top and concentration values are plotted from left to right. Read up from mg/l Standard and right of mg/l meter reading; when the line meets, place dot.
4. Plot each increment. Draw a line from first plot to last, ensuring a straight line is accomplished. Reanalyze standards which are not in line.

## CHAPTER 6 SAFETY

### 6.1 INTRODUCTION

A wastewater treatment plant exposes an operator to many potentially hazardous conditions; however, it need not be an unsafe place to work. Adherence to safety rules and common sense are generally sufficient to protect the operator from injury.

The Shaw AFB wastewater treatment plant contains various potential hazards similar to those existing in any wastewater treatment plant. The major types of hazards associated with such a facility are:

1. A potential for occurrence of injuries.
2. Handling of hazardous chemicals.
3. Exposure to various gases at abnormal concentrations.
4. Exposure to infectious diseases.

Due to the presence of these hazards, plant personnel must exercise caution in all their activities around the wastewater treatment plant and must take the steps necessary to protect all visitors to the plant from dangers unknown to them. A good plant safety program and safe working procedures and conditions are the keys to voluntary compliance with the Occupational Safety and Health Act of 1970 (OSHA). This section describes methods for achieving these safety objectives at the Shaw AFB facility. Some of the primary benefits of an effective safety program include lower operating costs, improved treatment efficiency, good employee morale, and positive community relations.

A constant conscious effort must be made both by plant management and by plant personnel to maintain a safe working environment. Every accident, injury, or work-related illness serves as an indication that there is a problem either with plant design, equipment specification or function, standard plant procedures, or employee assignment, capabilities, or training. Ideally, such problems should be recognized and remedied prior to occurrence of any undesirable situations. However, if an accident should occur, the source of the problem should be sought out and remedied immediately.

Shaw AFB currently has a detailed safety program for the WWTP. Safety procedures are based on AFOSH Safety Standards. A work place hazard analysis of the

WWTP and related job tasks has been performed. From the hazard analysis, specific safety procedures have been developed. Examples of these specific procedures include:

- Safe handling of chlorine cylinders,
- Changing chlorine gas cylinders,
- Working around open tanks,
- Chemical handling, and
- Working around operating mechanical and electrical equipment.

Other hazardous aspects of the Shaw AFB WWTP safety program include:

- Provision of appropriate personal protective equipment for plant personnel,
- Emergency procedures for activities such as fire reporting, personnel evacuation and personnel injury.

This section of the O&M Manual is designed to present additional safety-related topics and to augment current procedures. Further references in the area of safety for the Shaw WWTP can be obtained from the Water Environment Federation. Some pertinent references include:

- *SM-2, Guidelines for Developing a Plant Safety Program.*
- *MOP-1, Safety and Health.*

## **6.2 IMPACT OF REGULATIONS ON SAFETY/GENERAL CONSIDERATIONS**

The OSHA regulations, which became law in 1971, were implemented to eliminate unsafe working conditions in American industries. Portions of this law are applicable to wastewater treatment works and cover the activities of both the management and operations personnel.

### **6.2.1 Management Responsibilities**

Plant management is responsible for the development, implementation, and administration of the health and accident prevention program. These duties include, but are not limited to, the following:

1. Provide the leadership necessary to assure and maintain employee interest and participation.
2. Be familiar with job requirements, plant layout, facilities, fire protection systems, and fire prevention needs to the degree that unsafe acts or unsafe conditions can be recognized, discussed, and corrected.
3. Be the focal point for coordination and review of accident investigations and reports.
4. Review and select applicable safety materials for display or distribution.
5. Cooperate and assist with outside agencies that need to inspect, survey, or acquire knowledge of specific operations (Occupational Safety and Health Administration [OSHA] compliance officers, health officials, fire department personnel, Air Force inspectors, and so on).
6. Review the safety program periodically and amend it when necessary.
7. Require that employees adhere to safe procedures in the performance of their job.

In addition to the above responsibilities, management must ensure that the workplace is free from identifiable hazards which could cause physical injury, disease, or death. Potential hazard points which must be examined include light, noise, walkway clutter, ventilation, defective equipment, hygiene facilities, personnel break areas, and many others.

Management also has the responsibility to provide all applicable protective equipment and tools that are required for the employees to carry out their work assignments. Protective equipment includes eye protection, body protection, and respiratory protection.

Management will also be responsible for providing safety training and instruction. This involves identifying and determining training needs and objectives. Efforts include hands-on and classroom training conducted by in-plant personnel. It also includes training by safety professionals (Red Cross, Fire Department), equipment and chemical suppliers, and other outside sources. Some of these types of programs are currently in place at the Shaw WWTP and should be continued. Additional training by equipment and chemical suppliers should also be pursued.

### **6.2.2 Employee Responsibilities**

The regulations outline responsibilities for the employees to follow. As mandated by OSHA, these occupational and safety standards are applicable to the actions of the staff in carrying out the assigned job duties. The employee must be a positive influence on the safety program. Each employee is the person most concerned for his/her safety and must assume certain duties and responsibilities to assure on-the-job safety. These include, at a minimum:

1. Knowing his/her job and applying safe work practices as guided by published plant work rules or procedures.
2. Recognizing the hazards of the job and taking precautions to ensure his/her safety and the safety of those around him/her.
3. Informing his/her supervisor of hazards or unsafe acts and making recommendations as to how to eliminate or minimize those hazards.
4. Actively participating and cooperating in the overall safety program.
5. Maintaining cleanliness at the job station and maintaining good personal health habits.
6. Reporting to work well-rested so that he/she is in a good state of mind, receptive to instructions, and physically capable of doing the job.

### **6.2.3 Safety Inspections**

Regular safety inspections must be performed to ensure that a safe work environment is maintained within the plant. Inspections should be performed monthly. The purpose of the inspection is to detect, identify, and control hazards before accidents occur.

Safety checklists should be developed for specific areas (tanks, pump stations) or items (fire extinguishers, first aid kits, and safety showers). The lists should be simple and brief and should not include unnecessary items. Unsafe conditions encountered during the inspection should be corrected in the most timely and cost-effective manner.

Hazardous conditions should be immediately brought to the attention of the NCOIC. All hazardous areas should be documented on AF Forms 457, USAF Hazard Report.

### **6.2.4 Accident Investigation and Reporting**

All accidents, injuries, and work-related illnesses must be reported immediately to the water and waste supervisor. This will provide compliance with laws and regulations designed to protect both the employer and the employee, as well as insuring that prompt and effective first aid, medical, or hospital treatment is given to the employee. Prompt reporting may help to reduce the severity of the injury as well as the amount of time lost off the job. The filing of a complete report serves two primary purposes. It serves as a record of the incident which can be used in settling any claims, and it is used by plant administration in determining what changes should be made to help prevent accidents, injury, or illness. On-the-job injuries should be reported to the Civilian Personnel Officer using Form CA-1. Near accidents should also be reported, as they may indicate an unsafe condition which should be corrected. A critical aspect of any safety program is an effective system for accident investigation, accident reports, report analysis, and corrective action.

### **6.3 PLANT PROTECTIVE DEVICES**

Several structures and devices have been incorporated into the Shaw AFB treatment plant design for the express purpose of providing a measure of safety to plant employees. It is imperative that these structures and devices be utilized consistently. The use of preventive measures to avoid accidents is highly preferable to the necessity for responsive measures.

#### **6.3.1 Handrails**

Hand railings and hand chains are provided on walkways around and over tanks, specifically at the clarifiers, influent wet well, aeration tanks, digesters, and chlorination chamber. These serve to protect plant employees from falls during routine operation inspections, particularly when surfaces are slippery. These devices are for the safety of operators and visitors and should not be bypassed by climbing over or cutting. Flotation rings are provided at the headworks structures, secondary clarifiers, aeration basins, and digesters for use in case of personnel falling into the tanks.

#### **6.3.2 Walkways**

Caution must be exercised on elevated walkways. Operators should visually check to see if all grates are in place before walking across them.

Anytime a walkway grating is removed for any reason, temporary barriers should be placed around the open area. Brightly colored tape or cloth should also be used to warn and protect the unwary.

#### **6.3.3 Belt and Coupling Guards**

All rotating and moving equipment is protected with belt and coupling guards and other safety devices. Guards are installed to keep anyone from accidentally getting clothes, tools, or bodily parts in contact with moving machinery. Guards are also installed to protect employees should a piece of belt, coupling, or other part break loose and be slung out of the machinery. Guards must be periodically checked for proper installation. They must never be removed while the machinery is in operation. Guards must never be left off "temporarily" for convenience reasons. Any missing guard must be replaced as soon as possible.

#### **6.3.4 Safety Signs**

Warning signs, properly placed, serve as reminders to the thoughtless and uninformed. The instructions outlined on all safety warning signs must be strictly obeyed. Care should be taken never to block the view of such signs, and any safety signs which have become illegible should immediately be replaced. Never take for granted that all activities can be performed in any given area. Every worker should read and understand all signs in the area in which he/she is working.

Flammable and explosive conditions can exist in some plant structures due to gases given off by the wastewater. "NO SMOKING" signs must be strictly obeyed. "EAR PROTECTION REQUIRED," "DANGER CHLORINE," and "DANGER, HIGH VOLTAGE" signs must also be strictly obeyed.

#### **6.3.5 Fire Extinguishing Equipment**

Fire fighting equipment (fire extinguishers) have been placed at strategic locations throughout the Shaw AFB wastewater plant. It is imperative that all personnel be familiar with the location and proper use of all fire fighting equipment.

Fire extinguishers are located at the following locations:

- New Laboratory (4)
- Old Laboratory Building (1)
- Building 300 (1)
- Chlorine Feed Room (1)
- Generator Room (1)
- RAS/WAS Pump Station (1)

Regular monthly inspections of this equipment must be made to assure that all units are functional and that all fire extinguishers contain a full charge. Annual inspections should also be performed by an outside contractor. Hydrostatic testing of fire extinguishers should also be conducted regularly, generally at 5-year intervals. In addition to these items, certain fire safety information must be posted throughout the plant, including emergency phone numbers and emergency response instructions.

Fire hazards are always present in areas where lubricants, solvents, and fuels are stored. Gasoline and other volatile liquids must be stored in containers made for the purpose. All spills from such materials must be cleaned up immediately; rags, paper, wood, or any other flammable material must not be allowed to accumulate in such storage areas. Fire extinguishers should be provided in all areas where there is electrical equipment or flammable materials.

## **6.4 PERSONAL PROTECTIVE DEVICES**

### **6.4.1 Hand Protection**

Cotton gloves afford protection for general handling of abrasives, sharp objects, and glassware. Where hand protection is desirable but finger dexterity is essential, surgical-type gloves are to be used. Leather work gloves are desirable when manual tasks such as shoveling and raking are necessary.

The operator is cautioned not to wear rings while working in the plant. A ring can catch on machinery or equipment and cause injury to the fingers and hands.

### **6.4.2 Foot Protection**

Safety shoes with built-in steel toe caps must be worn where heavy objects are customarily handled or there are other foot hazards. Rubber-soled safety shoes should be worn where there is a considerable amount of water, acid, or other chemical present on the floors. Safety shoes should also provide ankle protection. Calf-high and hip-high rubber boots may be required when working in flooded areas. Rubber boots should also meet standards of toe, sole, and arch protection.

### **6.4.3 Body Protection**

Laboratory coats, aprons, smocks, coveralls, pants, jackets, hoods, and similar garments need to be used, when indicated, for protection of the body and clothes from corrosive chemicals.

Generally, operations employees should wear long pants and long-sleeve shirts. Rain suits can be worn when working in areas where sludge, water, and wastewater may be encountered, as well as for protection from the weather.

### **6.4.4 Eye Protection**

In the wastewater treatment plant, eye protection is necessary when working in the vicinity of operating pumps, performing maintenance, or working under or near piping, valves, and open top tanks where splashing can occur. Some form of protection must always be used in the laboratory when carrying out any operation which contains a possibility of liquid splashing.

Eye protection equipment must provide adequate protection against the particular hazards for which they are designed, and be reasonably comfortable when worn under

designated conditions. Protection equipment should fit snugly and not unduly interfere with the movements of the wearer. They should have adequate durability and be capable of being disinfected and easily cleaned. Persons requiring corrective lenses should be issued prescription safety eyewear with appropriate side shields. For short periods, they can wear goggles or face shields over their own glasses.

#### **6.4.5 Safety Shower and Eyewash Facilities**

At this writing, one safety shower/eyewash facility is located in the new Lab, and an eyewash unit is located at the old Lab building. All employees should be familiar with the location and use of this equipment.

The showers and eyewash must be maintained in good working order. Monthly inspections must be conducted to insure the proper operation of the facilities. Additionally, the shower and eyewash must be cleaned periodically to insure cleanliness. Access to the safety shower must always be kept clear in case of an emergency.

#### **6.4.6 Noise Protection**

Noise is generated at a wastewater treatment plant due to the large numbers of mechanical equipment required for the treatment processes. Prolonged exposure to excessive noise can cause hearing loss. The loss can be very slow and usually goes unnoticed until it is too late. Hearing loss from noise exposure can be permanent.

Anytime an employee is to be working in an area of excessive noise, personal protection devices must be used. There are a number of devices available including ear plugs and ear-muff type protectors. "EAR PROTECTION REQUIRED" signs must be strictly obeyed.

#### **6.4.7 Respiratory Protection**

Collection systems and wastewater treatment plants sometimes contain contaminated atmospheres that are dangerous to the respiratory system. Some of the hazards commonly found are chlorine gas, carbon monoxide gas, paint or solvent fumes, dust or particulates, hydrogen sulfide gas, and lack of oxygen. There are several kinds or types of respirators available with each one designed for a specific purpose, type of contaminant concentration, and period of time to be used. For example, respirators range from a simple dust mask to fully self-contained breathing apparatus (SCBA).

Employees must be fully trained on the job in how to wear and use respiratory devices. If respirator usage is only occasional or infrequent, a periodic skill and knowledge test is required. Ideally, this should be done monthly; at a minimum, quarterly. An outside group, such as the fire department, should be utilized to verify and augment this training. All training on SCBAs should be documented in a safety log.

All respiratory protection equipment must be inspected weekly and monthly. The respirators must be cleaned and all parts tested, inspected, and made ready for immediate operation. Procedures for inspection and storage are provided for each SCBA by the manufacturer.

#### **6.4.7.1 Self-Contained Breathing Apparatus**

When an employee must enter an atmosphere that is immediately dangerous to life, a self-contained breathing apparatus (SCBA) must be used. Such devices provide complete respiratory protection in all toxic or oxygen-deficient atmospheres. This type of respirator includes a high pressure cylinder of air, a cylinder valve, a demand regulator, a facepiece, and tube assembly. To use, the worker adjusts the facepiece, turns on the cylinder valve, and breathes in to draw the air through the demand regulator to the facepiece. The worker must exhale to the surrounding atmosphere through the exhalation valve. This type of unit can generally only be used for 30 to 60 minutes at a time. Two SCBAs are provided at the Shaw AFB WWTP. One is for use at the sulfur dioxide chlorine facility and one for use in old Lab.

#### **6.4.8 Medical Services and First Aid**

The names, locations, and telephone numbers of doctors, hospitals, and emergency response services will be posted in locations of high visibility. These lists should be updated at least annually. All employees must know where these notices are posted.

At least one well-maintained first aid kit must be kept readily available in the Shaw AFB Facility. All employees should be trained in the use of the contents of the first aid kits.

Life rings are located at the equalization basin, aeration basin, backwash water tank, clarifiers, digesters, and chlorine contact chambers.

The plant has a combustive gas/oxygen meter to insure safe entry into vaults.

Employees should maintain current certification in cardio-pulmonary resuscitation (CPR). Only these persons should attempt to administer cardiac life support. Improperly performed CPR is likely to cause serious damage to ribs and internal organs without sustaining breathing and heart functions.

Emergency numbers for the Shaw AFB wastewater treatment plant include:

Hospital/Ambulance/Emergency	-	3111
Fire - on base	-	117
Air Police	-	2222
		2493 (nonemergency)

## 6.5 PERSONAL HEALTH

Because of the sometimes cramped quarters and corrosive or dangerous materials found in treatment plants, it is necessary for the operations staff to keep alert to all possible hazards when performing routine or emergency tasks. Also, remember that visitors to the Shaw AFB wastewater treatment plant are not as well informed as you are, so caution them to keep their hands off plant equipment. Discussed below are several areas of concern.

### 6.5.1 Hygiene/Bacterial Infection

Wastewater always presents a potential health hazard. Operators should be advised to keep fingers from the nose, mouth, and eyes. A majority of hazardous and/or infectious materials are carried on the hands of workers. Wastewater treatment plant workers can well take note of the slogan commonly used by bacteriologists, "a good bacteriologist never places his hands above his collar while at work." After work and before eating, the hands should be washed thoroughly with plenty of soap and hot water. The nails should be kept short and foreign material removed with a nail file or stiff soapy brush. When the hands are soiled, smoking pipes, cigarettes, or cigars may introduce hazardous material into the mouth.

Hazardous materials can also be transmitted to the body from contaminated tools and lab equipment. Never use the mouth to draw samples into pipettes, as this could easily cause hazardous materials to be introduced into the mouth.

Gloves should be worn to prevent infection while cleaning equipment, handling sludge, taking or handling samples, or handling any tools or equipment within the plant where they can safely be worn. Gloves are particularly important when the hands are chapped or the skin is broken from a wound.

Food and drink must be kept in the Control Building. Never store food in any container or refrigerator where wastewater samples are stored, as this poses grave dangers of contamination.

Cuts received while working should receive prompt first aid. All cuts, no matter how minor, should be reported.

### 6.5.2 First Aid

The importance of first aid kits cannot be overemphasized. All employees must know their locations and understand the use of their contents. Prompt attention to all injuries is important. For all but minor injuries, a doctor should be called. Red Cross courses in first aid afford an excellent opportunity for training. The fire department and/or emergency response service should be contacted immediately whenever emergency reactions involve resuscitation or emergency handling of gas mishaps.

## 6.6 PLANT HAZARDS AND SAFETY PROCEDURES

The following paragraphs describe hazards which could be present in certain parts of the Shaw AFB wastewater treatment plant and recommended methods to reduce those hazards. Risk of injury can be reduced by always remembering to think things through before starting a job.

### 6.6.1 Fire and Explosion Hazards

It cannot be overemphasized that every wastewater treatment plant operator must obey "No Smoking" signs and should be cautioned as to the danger of smoking, dropping lighted matches, burning tobacco, or using open flames in the Shaw AFB facility. An igniting spark can even be created in removing manhole covers, and explosions from this can occur.

Gasoline, solvents, and other nondomestic waste can be found in the wastewater influent. The vapors from these fluids, when mixed with air in the right proportions, can explode violently if ignited. Investigations by the National Bureau of Mines have shown that gasoline and petroleum vapors will be found in the lower portion of manholes or sewers and in greater concentration just above the liquid surface. Due regard must be made for the time of the year, the velocity and direction of the wind, and barometric conditions. They have also found that explosions of such vapors are generally extremely destructive.

In any area where explosive or flammable gases may tend to accumulate, such as manholes or confining structures, an explosimeter should be used to detect such gases prior to entering or working in such areas. Detailed safety considerations for confined spaces are discussed in Section 6.8.

Good housekeeping practices are important to fire prevention. The accumulation of rubbish should be prevented, and all oil-soaked and paint-soaked rags should be placed in covered metal containers. Direct access to all exits, stairs, and fire fighting equipment must be kept clear of any obstructions. All combustible materials must be kept away from heat sources and other ignition sources.

Each operator should be familiar with the location of the fire extinguishers. The plant staff must be trained in the use of fire extinguishers and other fire fighting equipment.

## 6.6.2 Gases

An ever-present danger in every wastewater treatment plant is the production and collection of noxious and/or harmful gases. These gases may also be flammable or explosive.

The following places at the Shaw AFB wastewater plant and collection system are most likely to be dangerous due to such gases:

1. Lift stations.
2. Manholes.
3. Inside any covered tank.
4. Pump rooms.

This list is not all-inclusive. Many other areas of the plant may contain accumulations of harmful, toxic, or flammable gases. A partial list of gases commonly found in wastewater treatment plants is provided on Table 6.1.

### 6.6.2.1 Hydrogen Sulfide

Due to the nature of the wastewater processed at the Shaw AFB facility, hazardous gases may be present in various areas of the plant. One of the most prevalent and dangerous gases present at wastewater treatment facilities is hydrogen sulfide ( $H_2S$ ). Hydrogen sulfide is a flammable, colorless gas that is soluble in water. Hydrogen sulfide is evolved whenever the pH of a wastewater is less than 8.0 and sulfur is present in its reduced form (sulfide). Accumulation of hydrogen sulfide can occur in sewer lines, various sumps and wet wells, and poorly ventilated areas where wastewater or sludge is present.

Acute exposure may cause immediate coma, which may occur with or without convulsions. DEATH MAY RESULT with extreme rapidity from respiratory failure. The toxic action of hydrogen sulfide is thought to be due to its binding of the iron, which is essential for cellular respiration.

Subacute exposure results in headache, dizziness, staggering gait, excitement suggestive of neurological damage, and nausea and diarrhea suggestive of gastritis. Fortunately, recovery from subacute exposure is usually complete.

Table 6.1 Characteristics of Gases Common to the Wastewater Industry

Gas and chemical formula	Specific gravity	Explosive limits LEL	Max. safe 60-min. exposure (% vol. in air)	Max. safe 8-hr exposure (% by vol. in air)	Common properties	Physiological effects	Location of highest concentration	Most common sources	Simplest and safest method of testing
Ammonia NH <sub>3</sub>	0.59	16	25	0.03	0.01	Colorless, sharp, and pungent	Irritates eyes and respiratory tract; toxic at 0.01%	Up high	Sewer gas
Carbon Dioxide CO <sub>2</sub>	1.53	Non-flammable	4.0-6.0	0.5	Colorless, odorless, nonflammable; may cause acid taste in large quantities	Acts on respiratory nerves; 10% cannot be endured for more than a few minutes	Down low but may rise if heated	Sludge, sewer gas, combustion carbon and its compounds	Oxygen deficiency Indicator, odor
Carbon Monoxide CO	0.97	12.5	74.2	4.0	0.005	Colorless, odorless, tasteless, non-irritating; flammable, explosive, poisonous	Combines with hemoglobin of blood causing oxygen starvation; fatal in 1 hr. at 0.1%; unconsciousness in 30 min. at 0.25% and causes headaches in a few hours at 0.02%	Up high specifically if in presence of illuminating gas	Manufactured fuel gas, flue gas, combustion and fires
Chlorine Cl <sub>2</sub>	2.49	Non-flammable	0.0004	0.0001	Yellow, green color; irritating, pungent odor; nonflammable and supports combustion	Irritates respiratory tract, causes irritation and burning of the skin, coughing, and pulmonary edema in small concentrations	Down low	Chlorine cylinder and feed line leaks	Chlorine detector
Ethane C <sub>2</sub> H <sub>6</sub>	1.05	3.1	15	No limit provided	oxygen percentage (at least 12%) is sufficient for life	Colorless, odorless, tasteless, flammable, explosive, non-poisonous	Act mechanically to deprive tissues of oxygen; does not support life	Natural gas	Combustible gas indicator, Oxygen deficiency Indicator

Table 6.1 (cont)

<b>Gasoline</b> $C_6H_{12} - C_8H_{18}$	<b>3.0-4.0</b>	<b>1.3</b>	<b>7</b>	<b>0.4-0.7</b>	<b>Varies</b>	<b>Color,</b> <b>flammable,</b> <b>explosive,</b> <b>odor noticeable</b> <b>at 0.03% con-</b> <b>centration</b>	<b>Symptoms of</b> <b>intoxication</b> <b>when inhaled,</b> <b>difficult</b> <b>breathing and</b> <b>convulsions;</b> <b>fatal at 2.43%</b>	<b>Down low</b>	<b>Service sta-</b> <b>tions, storage</b> <b>tanks and</b> <b>dry cleaning</b> <b>operations</b>	<b>Combustible</b> <b>gas indicator;</b> <b>oxygen</b> <b>deficiency</b> <b>indicator</b>
<b>Hydrogen</b> <b>Sulfide</b> $H_2S$	1.19	4.3	46	0.02-0.03	0.001	Rotten egg odor in small concentrations; colorless, flammable, and explosive	Paralyzes the respiratory sys- tem; lessens the sense of smell as concentration in- creases; rapidly fatal at 0.2%	Down low; can be higher if air is hot and humid	Coal gas, petroleum, sewer gas and sludge gas	Lead acetate paper, lead acetate ampoules, H <sub>2</sub> S detector
<b>Methane</b> $CH_4$	0.55	5	15	No limit providing sufficient oxygen (at least 12%) is present	—	Colorless, odorless, tasteless, explosive, flammable, and non-poisonous	Deprives tissues of oxygen; does not support life	At top, increasing to certain depth	Digestion of sludge	Combustible gas indicator; oxygen deficiency Indicator
<b>Nitrogen</b> $N_2$	0.97	Non- flammable	—	—	—	Colorless, tasteless, odorless, and non-flammable	In very high concentrations, reduces oxygen intake; does not support life	Up high and sometimes in low areas	Sewer and sludge gas	Oxygen deficiency Indicator
<b>Oxygen</b> (in air) $O_2$	1.11	Non- flammable	—	—	—	Colorless, odorless, tasteless; supports combustion	Normal air con- tains 20.93% O <sub>2</sub> . Below 19% con- sidered deficient; 13% dangerous; below 5% fatal	Variable at different levels	Oxygen deficiency from poor ventilation and chemical combustion of O <sub>2</sub>	Oxygen deficiency indicator
<b>Sludge</b> <b>gas</b>	varies	5.3	19.3	Varies with composition	—	Flammable, practically odorless, and colorless	Will not support life	Up high	Digestion of sludge	Combustible gas indicator, oxygen deficiency Indicator

In areas where exposure to hydrogen sulfide exceeds 10 ppm, workers should wear full-face canister gas masks or air respirators. Because hydrogen sulfide is a flammable gas, workers must shut off ignition sources and use non-igniting/sparking equipment in the presence of hydrogen sulfide.

First aid for exposure to hydrogen sulfide is to call for medical aid, move victim to fresh air, give artificial respiration if breathing has stopped, or oxygen if breathing is difficult. If eyes have been exposed to hydrogen sulfide, they should be flushed with plenty of water.

## 6.7 ELECTRICAL MAINTENANCE SAFETY

Nearly all the equipment within the Shaw AFB facility is operated by electricity. Maintenance and day-to-day activities require personnel to handle and control this equipment. Unless safe work practices are strictly observed, serious injury or death can result.

Ordinary 120 V electricity may be fatal. Extensive studies have shown that currents as low as 10 to 15 mA can cause loss of muscle control and that 12 V may, on good contact, cause injury. Therefore, all voltages should be considered dangerous. Most electrical systems at wastewater treatment plants operate at voltages from 120 to 4000 or more. All electricity should be treated cautiously and without guessing as to the nature of the electrical circuit.

Electricity kills by paralyzing the nervous system and stopping muscular action. Frequently, electricity may hit the breathing center at the base of the brain and interrupt the transmission of the nervous impulses to the muscles responsible for breathing. In other cases, the electrical current directly affects the heart, causing it to cease pumping blood. Death follows from lack of oxygen in the body. It cannot be determined which action has taken place; therefore, a victim must be freed from the live conductor promptly by use of a dry stick or other nonconductor, or by turning off the electricity to at least this point of contact. Never use bare hands to remove a live wire from a victim or a victim from an electrical source. Next, cardio-pulmonary resuscitation or artificial respiration should be applied immediately and continuously until breathing is restored, or until a doctor or emergency medical technician arrives.

### 6.7.1 General Electrical Safety Rules

1. As long as you are not grounded, that is, as long as current cannot pass through your body to the ground, you are safe. While working on electrical circuits, do not touch the switch box cabinet or any other object, such as a pipe, that will give electric current a path through your body. Do not stand in water and, if possible, place a rubber mat under your feet.
2. Allow only authorized people to work on electrical panels.
3. Keep rubber mats on the floor in front of electrical panels.
4. Treat all electrical wires and circuits as "live," unless certain they are not.

5. Never work alone on energized equipment that operates at or above 480 V. When two employees work together, one can double-check the other, and there is always one employee available to de-energize circuits, apply first aid, or summon assistance in the event of a mishap.
6. Use approved rubber gloves.
7. Electrical control panels should never be opened unless the job requires it.
8. No part of the body should be used to test a circuit.
9. Always work from a firm base, as loss of balance may cause a fall onto energized busses or parts. Electrical parts should be covered with a good electrical insulator such as a rubber blanket.
10. No safety device should be made inoperative by removing guards, using oversized fuses, or blocking or bypassing protective devices, unless it is absolutely essential to the repair or maintenance activity, and then only after alerting operating personnel and the maintenance supervisor.
11. All tools should have insulated handles, be electrically grounded, or double insulated.
12. Jewelry should never be worn when working on electric circuits.
13. Use fuse pullers to change fuses.
14. Never use metal ladders, metal tape measures, or other metal tools around electrical equipment.
15. Keep wires from becoming a tripping hazard.
16. When performing electrical work, even simply energizing a piece of equipment, observe "No Smoking" signs.
17. When working around electrical equipment, keep your mind on the potential hazards at all times.

#### **6.7.2 Holding and Locking Out Electrical Circuits**

The most important safety requirement in electrical maintenance is to have and adhere to a good system for holding and locking out electrical circuits when equipment is being repaired. Unexpected operation of electrical equipment that can be started by

automatic or manual remote control may cause injuries to persons who happen to be close enough to be struck.

When motors or electrical equipment require repair, the circuit should be opened at the switch box, and the switch should be padlocked in the "OFF" position and tagged with a description of the work being done, the name of the person, and the department involved.

All personnel involved in maintenance work should be instructed in the following lock out procedure:

1. Alert the proper personnel: supervisor, affected operations staff.
2. Before starting work on an engine or motor line shaft or other power transmission equipment, or power-driven machine, make sure it cannot be set in motion without your permission.
3. Place your own padlock on the control switch, lever, or valve, even though someone has locked the control before you--you will not be protected unless you put your own padlock on it.
4. When through working at the end of your shift, remove your padlock or your sign and blocking, never permit someone else to remove it for you, and be sure you are not exposing another person to danger by removing your padlock or sign.
5. If you lose the key to your padlock, report the loss immediately to your supervisor and get a new padlock.
6. After repair, clear personnel from area BEFORE closing the breaker.

### **6.7.3 Explosion-proof Equipment**

Before breaking the seal on an explosion-proof enclosure, make certain that the work area has good ventilation. A combustible vapor check should be made. Nearby equipment and facilities should be shut down if practical. The area should be continually monitored for vapors, and only non-sparking, nonferrous tools should be used. On completion of the work, make certain that the explosion-proof fittings have been adequately resealed.

#### 6.7.4 Fire Extinguishers

At all motor control centers, transformer banks, and switchgear installations, fire extinguishers rated "Class C" for use on fires at electrical equipment should be mounted in the immediate vicinity. Water or other conductive liquids and materials that heat should never be used on electrical fires.

## 6.8 CONFINED SPACE SAFETY

A large percentage of the fatal accidents that have occurred in wastewater treatment plants have occurred in confined spaces. Clearly the problem is a lack of knowledge of the dangers involved in entering and working in confined spaces and the proper procedures to follow to prevent accidents.

### 6.8.1 Definition of Confined Space

A "confined space" is defined as any enclosed or semi-enclosed space that has restricted means for entry and exit and is not intended for continuous occupancy. Typical confined spaces in the wastewater industry are manholes, metering stations, valve or siphon chambers, digestors, silos, empty tanks, pits or any other area in the system that has direct contact with wastewater, sludge, sludge gas, or conduits carrying these substances.

### 6.8.2 Classification of Confined Spaces

Confined spaces are classified based upon existing or potential hazards. The two classifications of confined spaces are nonpermit confined space and permit-required confined space. A nonpermit confined space does not contain atmospheric hazards or have the potential to contain any hazard capable of causing death or serious physical harm. Examples of nonpermit confined spaces include vented vaults or motor control cabinets. These spaces have either natural or permanent mechanical ventilation to prevent the accumulation of a hazardous atmosphere, and they do not present engulfment or other serious hazards. A permit-required space has one or more of the following characteristics:

- Contains or has the potential to contain a hazardous atmosphere.
- Contains a material that has the potential for engulfing a person.
- Has an internal configuration such that a person could be trapped by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross-section.
- Contains any other recognized serious safety or health hazard.

The plant safety representative shall evaluate the workplace to determine if any spaces are permit-required confined spaces. Procedures described in paragraphs 6.8.3 through 6.8.10 apply only to permit-required spaces. Since nonpermit spaces are free of

atmospheric or safety hazards, they do not require special entry protocols. If there are changes in the use or configuration of a nonpermit confined space that could increase the hazards to the entrants, the plant safety representative shall reevaluate the space and reclassify it as a permit-required space if necessary.

### **6.8.3 Warning Signs**

A plant that contains permit-required confined spaces must post warning signs at the entrance to these spaces. Signs must, as a minimum, contain the following language:

DANGER  
PERMIT-REQUIRED CONFINED SPACE  
DO NOT ENTER

### **6.8.4 Permit-Required Confined Space Entry Permit System**

Employees must enter permit-required spaces in accordance with the plant's written permit-required confined space entry program. The written program shall be developed by the plant safety representative or designee and must address the following items:

- Measures necessary to prevent unauthorized entry into confined spaces.
- Methods for identifying and evaluating the hazards of the confined space prior to entry.
- Procedures and practices necessary for safe entry.
- Safety equipment necessary to conduct operations.
- Methods to evaluate space conditions during entry operations.
- Designated persons who are to have active roles in confined space operations (for example, entrants, attendants, and entry supervisor) and their duties.
- Methods to apprise contractors of precautions or procedures to implement when hired to conduct operations in a permit space.

### 6.8.5 Entry Permit

Entry into any area designated as a permit-required confined space will require a permit. The permit is an authorization and approval in writing that specifies the location and type of work to be done and certifies that all existing hazards have been evaluated and necessary protective measures have been taken to ensure the safety of each worker. The entry permit must address the following items:

- The permit space to be entered.
- The purpose of the entry.
- The date and the authorized duration of the entry permit.
- Names of the persons who will enter the confined space (entrants).
- Names of the persons who will be attendants.
- The name of the entry supervisor.
- The hazards of the confined space to be entered.
- The measures used to isolate the permit space and to eliminate or control the hazards before entry into the confined space.
- Acceptable entry conditions.
- The results of initial and periodic tests accompanied by the names or initial of the tester.
- The rescue and emergency services and the means used for summoning the service.
- The communication procedures used by entrants and attendants to maintain contact during the entry.
- Equipment, such as personal protective equipment, testing equipment, communications equipment, alarm systems, and rescue equipment.
- Other information necessary to ensure employee safety, given the circumstances of the particular confined space.

Once the entry has been completed, the plant safety representative will cancel the permit. Canceled permits must be maintained by the plant for at least 1 year. An example of a confined-space entry permit is included at the end of this section.

### 6.8.6 Equipment for Permit-Required Entry

The following is a list of equipment that must be considered prior to entering and working in permit spaces:

- Ventilation equipment needed to obtain acceptable airborne concentrations.
- Atmospheric-testing equipment to identify oxygen deficiency, combustible gases, and suspected toxic gases (e.g., hydrogen sulfide).
- Communication equipment for entrants and attendant.
- Personal protective equipment (e.g., respirators, hard hats), insofar as feasible engineering controls or work practices do not adequately protect employees.
- Lighting equipment to enable employees to work safely and exit quickly in the event of an emergency.
- Pedestrian or vehicle barriers (e.g., traffic cones, barricades, warning signs, traffic flags) to protect entrants from external hazards.
- Ladders for safe entry and egress.
- Any other equipment necessary for the entry into and rescue from the confined space.

### 6.8.7 Atmospheric Testing of Permit-Required Confined Spaces

All permit-required confined spaces must be considered dangerous before entry until proven safe. Air monitoring shall be performed before removing the cover, if practical. Some lids have openings through which a probe may be inserted. If not, the lid must be carefully removed using appropriate tools, and the atmosphere shall be tested before entry.

The principal atmospheric tests will be for oxygen deficiency and explosive and toxic gases. Combination meters are available that will give an indication of the percentage of oxygen and the percent of the lower explosive limit of the tested atmosphere. Additionally, the atmosphere shall be tested for toxic gases such as hydrogen sulfide, carbon monoxide, methane, carbon dioxide, or other suspected gases or vapors.

It is important to understand that some gases or vapors are heavier than air and will settle to the bottom of the space, whereas some gases are lighter than air and will be found around the top of the confined space as shown in Figure 6.1.

Test all areas (top, middle, bottom) of a space. Entry will be allowed only when the following atmospheric conditions are met:

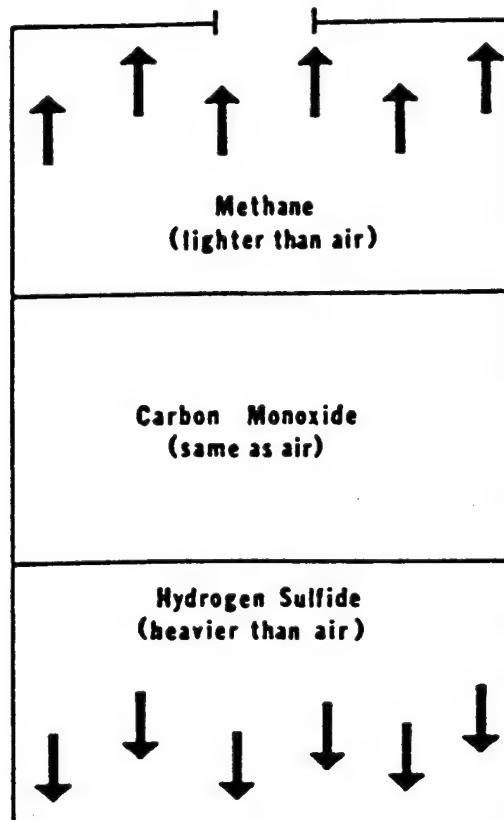
- The oxygen concentration in the confined space is greater than 19.5 percent and less than 23.5 percent by volume.
- The presence of flammable gases or vapors is less than 10 percent of the lower flammable limit.
- Potential toxic gases or vapor are present at concentrations below the OSHA permissible exposure limit (e.g., less than 10 ppm for hydrogen sulfide).

If atmospheric readings do not comply with acceptable entry parameters, then ventilation of the space is required. A blower for positive displacement of the atmosphere is often used. Allow sufficient time for the blower to displace three times the volume of the space. Next, retest the space to verify that acceptable concentrations have been met before any entry to the space is made. The blower shall remain in operation throughout occupancy of the space.

When using gasoline- or diesel-powered blowers, ensure that the exhaust gas from the engine is not drawn into the space by the blower. If a hazardous atmosphere persists in spite of ventilation, it will be necessary for the employee to use proper respiratory protection equipment. A positive-pressure self-contained breathing apparatus or positive-pressure airline respirator with a 5-minute escape tank is frequently used.

Personnel working in a permit-confined space must be equipped with a continuous atmospheric monitoring device. This is true even if the atmosphere was found to be safe initially, since conditions can change. Equipment used for continuous monitoring of the atmosphere shall be explosion-proof and equipped with an audible alarm that will alert employees when a hazardous condition develops.

An employee's well-being depends on the proper functioning of safety equipment. Careful, regular maintenance of the monitoring equipment is essential. All monitoring instruments must be calibrated prior to use and records of calibration maintained. The



Atmospheric Testing: From the Outside, Top to Bottom

limitations and possible sources of error for each instrument must be understood by the operator.

#### **6.8.8 Isolating the Permit Space**

Whenever entry into a permit-confined space is necessary, the space must be isolated from all other systems. This is to insure that injury does not occur.

Blanks must be used to physically isolate all lines into the confined space. Shut-off valves or pipelines to the space must be locked in the closed position and tagged for identification. Pumps and compressors connected to these pipelines must be locked out and tagged to prevent accidental activation. In continuous systems, where complete isolation is not possible (e.g., sewers), specific written safety procedures should be developed and used.

Electrical isolation of the confined space is necessary to prevent accidental activation of moving parts that would be hazardous to the worker. Circuit breakers or disconnects should be locked out and tagged in the off position with a key-type padlock. The only key is to remain with the person working inside who locked the breaker. If more than one person is inside the space, each person should place his or her own lock on the circuit breaker.

Mechanical isolation of moving parts can be achieved by disconnecting linkages or removing drive belts or chains. Equipment with moving mechanical parts should also be blocked in such a manner that there can be no accidental rotation. Remember, lives are at stake, and all of these steps are equally important. All lock out and tag out procedures must conform to OSHA standards (see CFR 1910.147).

#### **6.8.9 Responsibilities and Duties of Personnel Conducting Permit-Required Confined Space Operations**

As stated in Paragraph 6.8.4, the plant's permit-required confined space entry program should designate personnel who have active roles in the program. Every permit-required confined space operation requires authorized entrant(s), an attendant, an entry supervisor, and access to rescue services.

Any person entering a permit-required confined space must know the potential hazards, including the signs or symptoms and consequences of exposure and the required

safety procedures. Entrants must be familiar with the proper use of equipment and should be in constant communication with the outside attendant. When an entrant recognizes signs or symptoms of exposure to hazardous substance or detects a prohibited condition, the entrant must inform the attendant of the problem and initiate evacuation.

The attendant remains outside the permit space during the entire operation and is responsible for maintaining an accurate count of entrants in the confined space. The attendant should communicate with entrants as necessary to monitor status. Similarly to entrants, the attendant must know potential hazards during entry, including signs, symptoms, and behavioral effects of exposure to hazardous substances. The attendant monitors activities inside and outside the space to determine if it is safe for the entrants to remain. The attendant is required to order an immediate evacuation of the space when one of the following conditions occur:

- A prohibited condition is detected in the space.
- The attendant detects the behavioral effects of hazard exposure in an entrant.
- The attendant detects a situation outside the space that could endanger the entrants.

In the event of an emergency requiring the rescue of an entrant, the attendant is only permitted to perform non-entry rescue (i.e., extracting personnel by use of retrieval systems) or to summon rescue services.

The entry supervisor is the individual responsible for the development of the permit and has overall accountability for the safety of the operation. The entry supervisor checks permit entries verifying that all tests specified have been conducted and that all procedures and equipment are in place prior to entry. Additionally, the entry supervisor ensures rescue services is readily accessible.

The nature of work in confined spaces makes emergencies a continual possibility, no matter how infrequently they actually occur. Emergencies occur quickly and unexpectedly and require immediate response. In an emergency, rescue personnel would either enter a permit space to remove entrants or would remain outside and pull out entrants by use of retrieval lines. The plant may either establish an in-house rescue team or make arrangements for off-site services (i.e., fire department). If off-site

emergency rescue services are to be used, the response time to the site must be within 4 minutes.

#### **6.8.10 Training for Permit-Required Confined Space Work**

Anyone entering a permit space must recognize and understand the potential hazards to health and safety associated with the operation. Personnel involved in permit space activities must be thoroughly familiar with the plant's permit-required confined space program and must receive training. The objectives of the confined space training program are:

- To make workers aware of the potential hazards they may encounter.
- To provide the knowledge and skills necessary to perform the work with minimal risk to worker health and safety.
- To ensure that workers can safely avoid or escape from emergencies.

The level of training should be consistent with the worker's job function and responsibilities. The training program must involve both classroom instruction and hands-on practice. Hands-on instruction should consist of entry and rescue drills. Employees must demonstrate proficiency in the knowledge and skills necessary for safe entry and response (proficiency may be demonstrated through oral or written examination or evaluation of field simulations).

Training is required before the employee is assigned to a confined space operation and when the employee's assigned duties change (e.g., when responsibilities change from entrant to attendant). Members of the in-house rescue team must practice confined space rescues annually. This training should consist of simulated rescues in which the team removes a mannequin or people from actual permit-required spaces.

## CHAPTER 7

### MAINTENANCE

#### 7.1 INTRODUCTION

The term "maintenance" has many definitions, but in an engineering sense, total maintenance may be defined as the art of keeping plant equipment, structures, and other related facilities in a suitable condition to perform the services for which they were intended. "Preventive maintenance" is defined as the activities required to prevent process shutdown, reduce the wear on all equipment, and extend the life of equipment and structures. "Corrective maintenance" is defined as the activities required to repair malfunctioning or inoperable equipment.

To ensure the continuous trouble free operation of the Shaw AFB wastewater treatment plant, an effective "total maintenance" program is required. A total maintenance program is a schedule that incorporates preventive maintenance and corrective maintenance activities. By regular inspection and maintenance of each piece of equipment and keeping accurate records of performed maintenance, problems can be anticipated and usually avoided, thus reducing events of equipment failure and unscheduled shutdowns.

Planning and implementing an effective preventive maintenance program are essential in producing quality effluent on a continuous basis. In this chapter, a recommended approach to plant maintenance is discussed in general terms. A preventive maintenance and lubrication schedule for servicing of the plant's equipment is provided. The schedule was compiled from equipment manufacturers' manuals and existing WWTP maintenance procedures. Frequency and type of required maintenance reflect these information sources. A manual record-keeping system for maintenance is also described. Forms for this record-keeping system are provided in Appendix B.

## 7.2 PREVENTIVE MAINTENANCE

Preventive maintenance may be defined as the art of preventing equipment failure by establishing a system of regular inspections and scheduled maintenance based on equipment repair history to detect trouble spots before they become the cause of major problems. Preventive maintenance is the key element in the plan for management of the maintenance function.

Typically, a preventive maintenance (PM) program includes the following:

1. Equipment inspection.
2. Lubrication.
3. Minor adjustments.
4. Housekeeping, keeping equipment clean.
5. Equipment rotation.
6. Record keeping and scheduling.

The following cite just a few advantages of an effective PM program:

1. Fewer Failures. A timely PM program uncovers problems before they become serious enough to cause equipment failure. As a result, routine adjustments and minor repairs take the place of failures.
2. More Planned Work. The timeliness of PM inspections uncovers those major jobs that require preplanning.
3. Fewer Emergencies. An effective PM program has every employee on the alert for those things that cause problems. As a result, fewer problems escape detection to generate an emergency situation.
4. Reduced Overtime. One of the largest contributing factors to overtime is the need to perform emergency repairs.
5. Extended Equipment Life. PM means timely adjustments, better lubrication, etc. Equipment treated in such a way rewards its users by lasting longer and, thus, is less costly to the system users.

### **7.2.1 Equipment Inspection**

The most critical part of the PM program is the "Operations and Maintenance Routine Check." This is the portion of the program that generates the advance information on the status of the equipment. This information provides the lead time that permits maintenance to be planned. The PM program then becomes "detection oriented" with the principal aim of uncovering problems before they become serious. Checksheets for the Shaw WWTP are included in Chapter 8 as part of the Standard Operations Procedures.

In the interest of making the best use of time and due to the fact that these two functions are inseparable, "operating conditions" and "maintenance conditions" are examined at the same time. Every item on a plant check list should be examined at least at the frequency indicated. It is good operating procedure to conduct this inspection at the beginning of a shift. Deficiencies found should be noted on a special "Trouble Report" or other approved form for requesting maintenance.

### **7.2.2 Lubrication**

Proper lubrication is essential to keeping treatment plant equipment operating. Lubricants are applied in a number of ways ranging from a hand-operated oil can to complicated automated systems. The success of any lubrication system is dependent upon the lubricator's attention to oil levels, applying the proper lubricant in the proper amount at the proper time, and on regular inspection of lubrication systems.

The basic rule of thumb for proper lubrication is that the right lubricant must be applied at the right place, at the right time, and in the right amount.

The proper lubricant is specified by the equipment manufacturer. Refer to the operating manual supplied to be sure you are using the proper lubricant.

### **7.2.3 Minor Adjustments**

An ounce of prevention is worth a pound of cure. Both operation and maintenance people must be constantly on the alert for minor problems and make the necessary repairs before major problems develop. This includes such things as:

1. Excessive leakage on packing.
2. Minor oil leaks.
3. Minor leaks on valves and fittings.
4. Belt adjustments.

Excessive leakage on packing, if not adjusted immediately, will ruin the packing and cause damage to shaft sleeves and shafts (some leakage around water lube packing is necessary). Minor leaks, if not stopped immediately, will soon develop into major leaks and major problems. V-belts, if not adjusted properly, will cause rapid wear of belts and possible breakdown of equipment. These are the types of items that the operator must be very aware of when making routine checks of the plant.

#### **7.2.4 Housekeeping**

Maintenance of a clean, safe, and orderly working environment is essential to efficient and effective plant operations. Plant housekeeping is the responsibility of all plant employees and must be performed on a continuous basis. Certain housekeeping functions can and should be performed by each employee as part of the normal daily work routine. These include:

1. Replacement of all tools and equipment to their normal storage locations.
2. Removal of trash, rocks, and other debris from work areas and walkways.
3. Proper storage of all cleaning solvents and other small chemical containers.
4. Proper disposal of all dirty or oily rags.
5. Thorough cleaning of an area once work in that area has been completed (may include washdown).
6. Prompt cleanup of all spills.
7. Reporting of any dirty, broken, or nonfunctional equipment.

#### **7.2.5 Tools and Tool Room Control**

An important aspect of preventive maintenance, as well as corrective maintenance, is the availability of proper tools to do the job. Tools should be stored in specific locations in the Shaw AFB wastewater plant control building. Specialty tools and delicate

Shaw AFB  
O&M Manual  
Chapter 7

instruments should be stored in restricted areas, and use of them should be carefully controlled by the plant superintendent or assistant superintendent.

### 7.3 PLANT MAINTENANCE PROGRAM

A Base-wide preventive maintenance program (Recurring Work Program) is established and is implemented for the WWTP. A computer list of equipment requiring maintenance, or Recurring Work Program Report (RWPR), is produced weekly. This report provides an equipment identification number, maintenance frequency, description of work, estimated and actual hours necessary to perform the activity, and status of work (see Figure 7.1). The RWPR serves as both a work order, and when the work is completed, a report on the work done. It is sent back to Civil Engineering where the computer record is updated. Items on the RWPR not finished that week will continue to appear on subsequent RWPRs until they are completed. In addition to the RWPR, a maintenance action sheet (MAS) is prepared for each piece of equipment requiring maintenance. The MAS contains a list of activities to be performed, the amount of time allocated per activity, the frequency of the activity, and the size of the crew needed (see Figure 7.2).



Figure 7.2

**ES** ENGINEERING-SCIENCEMAS Task Detail Screen

Cost Center: VLSBA 469

MAS No: 6 Title: VAR SP POSITROL

Task No Freq Description

001 L LOAD OIL &amp; TOOLS ON TRUCK

INFORM OPERATOR SYSTEM WILL BE DOWN

OBSERVE THE OPERATION OF THE EQUIPMENT AND THE PHYSICAL CONDITION OF THE OIL

LOCKOUT THE ELECTRICAL SYSTEM

CHANGE OIL AND CHECK THE OLD OIL FOR CONTAMINATION

REMOVE LOCKOUT AND CHECK OPERATION OF THE PUMP UNIT

CLEAN MAINT AREA AND INFORM OPERATOR SYSTEM IS BACK ON LINE

RECORD INFORMATION IN FACILITY RECORD

Work Sequence Number: 1

Hours to perform Task: 2.400

Crew Size: 2

Number of Occurrences: 1

Heavy Equip Required? N

Total Task Hours: 2.400 (Hours X Occurrences)

EPS Standard Used? N

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(1)Keys (2)List Hrs by Freq (4)Prev (5)Next (6)PMI Book (7)EPS Book  
(9)Modify (11)Add Task (12)Delete (15)Print (16)Return (32)Exit

## 7.4 MAINTENANCE RECORD KEEPING AND SCHEDULING

This section outlines additional maintenance record keeping to ensure continued efficient operation of the Shaw AFB wastewater treatment plant. This maintenance data and record keeping are essential to a total maintenance program. These forms which are included in Appendix B can be copied and stored in a loose-leaf binder for easy access and use.

### 7.4.1 Equipment Data

Data cards should be prepared for each item of equipment in the system. Format examples of data cards for pumps, motors, and other mechanical equipment are presented in Figures B.1, B.2, and B.3. Any convenient indexing system may be used, but it is suggested that all mechanical equipment be filed according to the ID number assigned to each piece of equipment.

Upon completion of all equipment data record forms, they should be filed according to system designation and in alphabetical order. These forms will save many hours in the future and will preserve nameplate data on equipment which is subject to obliteration, abrasion, and painting.

### 7.4.2 Spare Parts Records

A number of spare parts should always be carried in stock to eliminate or reduce the possibility of an equipment item being out of service for an extended period of time due to a lack of parts. The type and number of spare parts to be maintained should be determined based upon the likelihood of failure, the shelf life of the part, the critical nature of the item, local availability of the part, and the time required to get the part when it is needed, if it is not stocked. The manufacturers' O&M literature contains lists of recommended spare parts.

Figure B.4 is a suggested form to serve as a means of maintaining a record of spare parts as they are placed on order, to record their receipt and issue, and to inventory the parts in stock.

#### **7.4.3 Inventory Control**

In addition to spare parts records for all plant equipment, a file system should also be used to maintain an inventory of expendable supplies, lubricants, and other miscellaneous items. Figure B.5 presents a sample inventory card to be used for this purpose.

## 7.5 PREVENTIVE MAINTENANCE SCHEDULE

This section presents the routine preventive maintenance (PM) and lubrication schedule for the equipment included in the Shaw AFB wastewater treatment plant. These schedules were derived from maintenance instructions contained in vendor literature. Equipment manuals should be consulted before performing any preventive or corrective maintenance. Vendor literature is located in the WWTP Control Building bookcase. The PM schedules are presented in Tables 7.1 through 7.32.

### 7.5.1 Safety Precautions

Before any maintenance or inspection is done on the equipment in the treatment system, it is of utmost important that several basic safety precautions be followed:

- a) Notify supervisory personnel of intention.
- b) Disconnect power to any applicable equipment, lock it out, and tag it. OSHA requires formal lock out procedures be practiced for mechanical and electrical work on all electrically driven equipment.
- c) Put on the proper protective gear for the material expected in the equipment.
- d) Check for power at the local hand switch to ensure that power is off, and test atmosphere for hazardous vapor levels if entering a confined space.
- e) Use tools fitted to the job, such as non-sparking for an explosive atmosphere.
- f) Do not enter any tank or structure considered a confined space unless all appropriate safety procedures are followed.
- g) Relieve the pressure, and drain all piping, valves, and pumps before disassembly.
- h) Immediately clean up spillage from nearby equipment or structures.
- i) Reassemble equipment per manufacturer instructions.
- j) Clear all personnel from immediate area of work before placing equipment back in service.

**TABLE 7.1**  
**Lift Station No. 306**  
**Preventive Maintenance Schedule**

<b>Weekly</b>
1. Conduct operational check. Look into wet well.
2. Grease pump and shaft bearings.
3. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
4. Check for leaks on pumps and piping. Put leaks on maintenance schedule.
5. Check pump for vibration, noise, and excessive heat. If excessive vibration is detected, check alignment of pump and motor. Observe vibration of long shaft.
6. Tighten or replace missing or loose nuts, bolts, or screws.
<b>Monthly</b>
1. Lubricate motor grease fittings.
2. Check electrical panels for loose or frayed wiring, tighten or replace. Check lights on control panel, replace as required.
3. Clean inside of control panel.
<b>Quarterly</b>
1. Remove and replace packing if needed.
2. Check overall condition of pump and housing.

**TABLE 7.2**  
**Lift Station No. 116**  
**Preventive Maintenance Schedule**

<b>Weekly</b>
<ol style="list-style-type: none"><li>1. Conduct operational check.</li><li>2. Clean exterior of equipment.</li><li>3. Check for corrosion on equipment throughout lift station. If corrosion does exist, put on maintenance schedule.</li><li>4. Check for leaks on pumps and piping. Put leaks on maintenance schedule.</li><li>5. Check running equipment for vibration, noise, and excessive heat. If excessive vibration is detected, check alignment. Observe vibration of long shafts.</li><li>6. Tighten or replace missing or loose nuts, bolts, or screws.</li><li>7. Inspect float system for proper operation.</li><li>8. Clean area.</li><li>9. Check audible alarm for operation.</li></ol>
<b>Monthly</b>
<ol style="list-style-type: none"><li>1. Lubricate pumps.</li><li>2. Check electric panels for loose or frayed wiring. Tighten or replace as required. Check lights on control panel, replace as required.</li><li>3. Clean inside of control panel.</li></ol>
<b>Semiannually</b>
<ol style="list-style-type: none"><li>2. Lubricate motors as per manufacturers' specifications.</li></ol>

**TABLE 7.3**  
**Lift Station No. T-28**  
**Preventive Maintenance Schedule**

<b>Weekly</b>
1. Conduct operational check.
2. Clean exterior of equipment.
3. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
4. Check for leaks on pumps and piping. Put leaks on maintenance schedule.
5. Check running equipment for vibration, noise, and excessive heat. If excessive vibration is detected, check alignment. Observe vibration of long shafts.
6. Tighten or replace missing or loose nuts, bolts, or screws.
7. Check operation of float system.
8. Clean area.
9. Check audible alarm for operation.
<b>Monthly</b>
1. Lubricate pumps.
2. Check electric panels for loose or frayed wiring. Tighten or replace as required. Check lights on control panel, replace as required.
3. Clean inside of control panel.
<b>Semiannually</b>
2. Lubricate motors as per manufacturers' specifications.

**TABLE 7.4**  
**Lift Station No. 600 (new)**  
**Preventive Maintenance Schedule**

<b>Weekly</b>
1. Conduct operational check.
2. Clean exterior of equipment.
3. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
4. Check for leaks on all piping. Put leaks on maintenance schedule.
5. Visually check operation of pumps.
6. Tighten or replace missing or loose nuts, bolts, or screws.
7. Check operation of float system.
8. Clean area, clean bar screen as required.
9. Check audible and visual alarms for operation.
10. Check pump alternation for operation.
11. Check condition of emergency generator, be sure generator is ready for emergency.
12. Check fuel tank level for generator.
13. Check macerator for proper operations.
<b>Monthly</b>
1. Check electric panels for loose or frayed wiring. Tighten or replace as required. Check lights on control panel, replace as required.
2. Lubricate macerator and automatic screen as needed.
3. Clean inside of control panel.
<b>Quarterly</b>
1. Exercise emergency generator.
<b>Semiannually</b>
2. Lubricate all motors as per manufacturers' specifications.

**TABLE 7.5**  
**Lift Station No. 600 (old)**  
**Preventive Maintenance Schedule**

<b>Weekly</b>
<ol style="list-style-type: none"><li>1. Conduct operational check when in service. Be sure all equipment is operational.</li><li>2. Clean exterior of equipment.</li><li>3. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.</li><li>4. Clean area.</li><li>5. When station is in operation, check pumps and piping for leaks. Put leaks on maintenance schedule.</li><li>6. Check condition and operation of bubbler system.</li><li>7. Insure that audible and visual alarms are operational if needed.</li></ol>
<b>Monthly</b>
<ol style="list-style-type: none"><li>1. Grease pumps if they have been in operation. Exercise pumps if they have not been in use for extended periods.</li><li>2. Check electric panels for loose or frayed wiring. Tighten or replace as required. Check lights on all panels. Replace as required.</li><li>3. Clean inside of control panels.</li><li>4. Bump pumps to insure operations.</li></ol>
<b>Semiannually</b>
<ol style="list-style-type: none"><li>1. Lubricate all motors as per manufacturers' specifications.</li></ol>

**TABLE 7.6**  
**Lift Station No. 1130**  
**Preventive Maintenance Schedule**

<b>Weekly</b>
1. Conduct operational check.
2. Clean exterior of equipment.
3. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
4. Check for leaks on pumps and piping. Put leaks on maintenance schedule.
5. Check running equipment for vibration, noise, and excessive heat. If excessive vibration is detected, check alignment. Observe vibration of long shafts.
6. Tighten or replace missing or loose nuts, bolts, or screws.
7. Check operation of float system.
8. Clean area.
9. Check alarm light and horn for operation.
<b>Monthly</b>
1. Lubricate pumps.
2. Check electric panels for loose or frayed wiring. Tighten or replace as required. Check lights on control panel, replace as required.
3. Clean inside of control panel.
<b>Semiannually</b>
2. Lubricate motors as per manufacturers' specifications.

**TABLE 7.7**  
**Lift Station No. HQ**  
**Preventive Maintenance Schedule**

<b>Weekly</b>
1. Conduct operational check.
2. Clean exterior of equipment.
3. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
4. Check for leaks on all piping.
5. Visually check operation of pumps and condition in wet well.
6. Check operation of float system.
7. Clean area.
8. Check alarm lights and audible alarm for operation.
<b>Annually</b>
1. Lift pumps and service according to manufacturers' specifications.

**TABLE 7.8**  
**Lift Station No. 1216**  
**Preventive Maintenance Schedule**

<b>Weekly</b>
1. Conduct operational check.
2. Clean exterior of equipment.
3. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
4. Check for leaks on all pumps and piping. Put leaks on maintenance schedule.
5. Check running equipment for vibration, noise, or excessive heat. If excessive vibration is detected, check alignment. Observe vibration of long shafts.
6. Tighten or replace missing or loose nuts, bolts, or screws.
7. Check operation of float system.
8. Clean area.
9. Check alarm light and horn for operation.
<b>Monthly</b>
1. Lubricate pumps.
2. Check electric panels for loose or frayed wiring. Tighten or replace as required. Check lights on control panel. Replace as required.
3. Clean inside of control panel.
<b>Semiannually</b>
1. Lift motors as per manufacturers' specifications.

**TABLE 7.9**  
**Lift Station No. 1600**  
**Preventive Maintenance Schedule**

<b>Weekly</b>
1. Conduct operational check.
2. Clean exterior of equipment.
3. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
4. Check for leaks on all pumps and piping. Put leaks on maintenance schedule.
5. Check running equipment for vibration, noise, or excessive heat. If excessive vibration is detected, check alignment. Observe vibration of long shafts.
6. Tighten or replace missing or loose nuts, bolts, or screws.
7. Check operation of float system.
8. Clean area.
9. Check alarm light and horn for operation.
<b>Monthly</b>
1. Lubricate pumps.
2. Check electric panels for loose or frayed wiring. Tighten or replace as required. Check lights on control panel. Replace as required.
3. Clean inside of control panel.
<b>Semiannually</b>
1. Lubricate motors as per manufacturers' specifications.

**TABLE 7.10**  
**Lift Station No. 0012**  
**Preventive Maintenance Schedule**

<b>Weekly</b>
1. Conduct operational check.
2. Clean exterior of equipment.
3. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
4. Check for leaks on all piping.
5. Visually check operation of pumps and condition in wet well.
6. Check operation of float system.
7. Clean area.
8. Check alarm lights and audible alarm for operation.
9. Check pump alternation for proper operation.
<b>Annually</b>
1. Lift pumps and service according to manufacturers' specifications.

**TABLE 7.11**  
**Lift Station No. 3227**  
**Preventive Maintenance Schedule**

<b>Weekly</b>
1. Conduct operational check.
2. Clean exterior of equipment.
3. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
4. Check for leaks on all pumps and piping. Put leaks on maintenance schedule.
5. Check running equipment for vibration, noise, or excessive heat. If excessive vibration is detected, check alignment. Observe vibration of long shafts.
6. Tighten or replace missing or loose nuts, bolts, or screws.
7. Check operation of float system.
8. Clean area.
9. Check alarm light and audible alarm for operation.
10. Check pump alternation for proper operation.
<b>Monthly</b>
1. Lubricate pumps.
2. Check electric panels for loose or frayed wiring. Tighten or replace as required. Check lights on control panel. Replace as required.
3. Clean inside of control panel.
<b>Semiannually</b>
1. Lubricate motors as per manufacturers' specifications.

**TABLE 7.12**  
**Lift Station No. 5630**  
**Preventive Maintenance Schedule**

<b>Weekly</b>
1. Conduct operational check.
2. Clean exterior of equipment.
3. Check for corrosion on equipment and throughout lift station. If corrosion does exist, put on maintenance schedule.
4. Check for leaks on all pumps and piping. Put leaks on maintenance schedule.
5. Check running equipment for vibration, noise, or excessive heat. If excessive vibration is detected, check alignment. Observe vibration of long shafts.
6. Tighten or replace missing or loose nuts, bolts, or screws.
7. Check operation of float system.
8. Clean area.
9. Check alarm light and audible alarm for operation.
10. Check pump alternation for proper operation.
<b>Monthly</b>
1. Lubricate pumps.
2. Check electric panels for loose or frayed wiring. Tighten or replace as required. Check lights on control panel. Replace as required.
3. Clean inside of control panel.
<b>Semiannually</b>
1. Lubricate motors as per manufacturers' specifications.

**TABLE 7.13**  
**Equalization Basin Blowers**  
**Preventive Maintenance Schedule**

<b>Daily</b>
1. Check motor and blower for excessive heat, noise, or vibration.
2. Check oil level. Add oil to maintain required level.
3. Check grease vents on blower. Vents must be open at all times.
4. Clean blowers and motors to prevent buildup of grease and oil.
5. Clean up area as required.
<b>Every 500 Hours</b>
1. Grease drive end bearings of blowers every 500 hours with recommended lubricants.
<b>Every 1500 Hours</b>
1. Drain oil from blower, flush blower, and refill with recommended oil.

**TABLE 7.14**  
**Grit Chamber Basin Blowers**  
**Preventive Maintenance Schedule**

<b>Daily</b>
1. Check motor and blower for excessive heat, noise, or vibration.
2. Check oil level. Add oil to maintain required level.
3. Check grease vents on blower. Vents must be open at all times.
4. Clean blowers and motors to prevent buildup of grease and oil.
5. Clean up area as required.
<b>Every 500 Hours</b>
1. Grease drive end bearings of blowers every 500 hours with recommended lubricants.
<b>Every 1500 Hours</b>
1. Drain oil from blower, flush blower, and refill with recommended oil.

**TABLE 7.15**  
**Grit Collector and Screw Conveyor**  
**Preventive Maintenance Schedule**

<b>Daily</b>
1. Check normal operations. Check for vibration or unusual noises in motors and drives.
2. Check for corrosion on equipment. Clean and paint as required.
3. Tighten or replace loose bolts, nuts, or screws.
4. Clean up area.
<b>Monthly</b>
1. Check oil level in gear boxes.
2. Visually inspection operation of chain.
<b>Quarterly</b>
1. Change oil in gear boxes and speed reducers as per manufacturers' instructions.
<b>Annually</b>
1. Grease all motors as per manufacturers' specifications.
2. Drain chambers and inspect wear shoes, chains, buckets, and all equipment including chambers walls for wear, corrosion, and deterioration.
3. Check condition of all bearings.

**TABLE 7.16**  
**Parshall Flumes (Influent, Effluent, RAS)**  
**Preventive Maintenance Schedule**

<b>Daily</b>
1. Make operational check.
2. Inspect flume for debris. Remove if present.
3. Check operation of flow meter. Check that float is riding correctly on fluid surface in stilling well.
<b>Monthly</b>
1. Check accuracy of meter by checking head in stilling well manually. Determine flow from rating curve provided by vendor, compare with chart flow.

**TABLE 7.17**  
**Screw Pumps**  
**Preventive Maintenance Schedule**

<b>Daily</b>
<ol style="list-style-type: none"><li>1. Check oil level in gear box. Keep oil at manufacturer's recommended level. If synthetic lubricants are used, the lubricant need not be changed. Otherwise, change lubricant every 2500 hours.</li><li>2. Visually check oil systems for leaks.</li><li>3. Check screw pump and lubrication equipment for excessive noise, heat, or vibration.</li><li>4. Visually check sump for debris.</li><li>5. Clean area as needed.</li><li>6. Check position of inlet slide gate.</li><li>7. Check setting of pump on controller.</li></ol>
<b>Weekly</b>
<ol style="list-style-type: none"><li>1. Check grease reservoir in bottom bearing. Add grease to prevent reservoir from running out of grease.</li><li>2. Check tension on V-belt, tighten as required.</li><li>3. Check entire screw pump and lubrication equipment for signs of corrosion. If corrosion is found, put on maintenance schedule.</li></ol>
<b>Monthly</b>
<ol style="list-style-type: none"><li>1 Grease top bearing.</li><li>2 Rotate screw pumps according to schedule.</li><li>3 Visually check pump for signs of wear or damage.</li></ol>
<b>6 Months</b>
<ol style="list-style-type: none"><li>1 Grease motor.</li><li>2 Tighten all bolts as needed.</li></ol>

**TABLE 7.18**  
**Screw Pump Motor Control Panel**  
**Preventive Maintenance Schedule**

**Annually**

1. Examine the inside of the motor control center for moisture, signs of previous wetness, or dripping. Seal any leaks found.
2. Check devices such as contactors, circuit breakers, disconnect switches, relays, pushbuttons, etc., for wetness, contamination, or corrosion. Dry, clean, or replace as necessary.
3. Remove accumulated dust or dirt using a brush, vacuum cleaner, or lint-free rags.
4. Examine all accessible electrical joints and terminals in the bus and wiring systems for signs of overheating or corrosion.
5. Tighten all bolts and nuts at joints that show signs of overheating or looseness. Replace all badly corroded or pitted parts.
6. Examine fuse clips for looseness. Replace as necessary.
7. Operate each switch or circuit breaker several times to make sure that all mechanisms are free and in proper working order.
8. Check fuses and circuit breakers for proper amperage ratings.

**DANGER: SUCH PANELS SHOULD BE CHECKED ONLY BY  
AUTHORIZED ELECTRICAL TECHNICIANS.**

**TABLE 7.19**  
**Screw Pump Dynamatic Adjustable AC Drive**  
**Preventive Maintenance Schedule**

<b>Daily</b>
1. Keep room free of dust and dirt at all times.
2. Ensure that ventilation system is operating.
3. Record pump setting on control panel.
<b>Quarterly</b>
1. Tighten all electrical connections. This should be done only by qualified electrical technician.

**TABLE 7.20**  
**Aeration Tanks**  
**Preventive Maintenance Schedule**

<b>Daily</b>
1. Inspect the aerators to ensure that all equipment is secure.
2. Inspect for and remove rags, strings, or other solids collecting on the cables or impellers.
<b>Monthly</b>
1. Check oil level in aerator gear boxes. Fill as needed in accordance with manufacturer's recommendations.
<b>Annually</b>
1. Drain and clean tanks, checking for cracks, leaks, deterioration, and drain valve conditions.
2. Check floating aerators. Service motors as required.
3. Paint all handrails and equipment as required.
4. Change oil in aerator gear boxes in accordance with manufacturer's literature.

**TABLE 7.21**  
**Secondary Clarifiers**  
**Preventive Maintenance Schedule**

<b>Daily</b>
1. Visually inspect splitter box for proper operation.
2. Observe operation of drive units. Look for accumulation of dirt, oil, or grease. Check for unusual noises, vibration, or heat. Clean or repair as required.
3. Observe surface skimmer. Observe for proper action on scum beach and reentry into tank.
4. Check weir levels.
<b>Monthly</b>
1. Check oil sump levels in gear boxes. Fill as necessary.
<b>Annually</b>
1. Drain clarifiers. Clean and inspect all submerged equipment.
2. Check scraper arms for clearance or damage.
3. Repair and paint as necessary.
4. Check torque overload switches.

**TABLE 7.22**  
**Tertiary Filters**

<b>Weekly</b>
1. Grease surface wash pump upper and lower grease fittings.
2. Check surface wash pump while running for unusual noise, heat or vibrations.
3. Grease all backwash pump lubrication fittings and check oil through reservoir site glass.
4. Check backwash pump for unusual noise, heat or vibration during operation.
<b>Monthly</b>
1. Check all air lines for leaks.
<b>Semi-Annually</b>
1. Change oil in backwash pump motor oil reservoir.
<b>Annually</b>
1. Remove backwash pump packing and packing assembly for inspection and/or repair.
2. Repack backwash pump and adjust packing as required.
3. Repack surface pump and adjust pumping as required.

**TABLE 7.23**  
**Chlorinator and Sulfurnators**  
**Preventive Maintenance Schedule**

<b>Daily</b>
1. Check operation of chlorinator and sulfurnators at least once per shift. Follow all safety procedures.
2. Clean roto meter as required.
3. Check gas detector for proper operation.
4. Be sure gas cylinders are chained in place.
5. Check vacuum. If vacuum is low, clean y-strainer in vacuum supply line. Clean nozzle and throat in ejector.
6. Clean area as required. Watch for corrosion and paint as required.
<b>Every 3 Months</b>
1. Conduct a performance check on all elements of chlorinator and sulfurnator systems. Follow all safety procedures. Use troubleshooting guides in equipment manual.

**TABLE 7.24**  
**Chlorine Contact Tanks**  
**Preventive Maintenance Schedule**

<b>Monthly</b>
1. Change contact chamber blower oil per manufacturers recommendations.
2. Check blower drive belts for proper tension and wear. Adjust or replace as needed.
<b>Annually</b>
1. Drain and clean tanks. Check for cracks, leaks, deterioration, and underwater piping conditions.

**TABLE 7.25**  
**Aerobic Digesters**  
**Preventive Maintenance Schedule**

<b>Annually</b>
<ol style="list-style-type: none"><li>1. Drain and clean tanks. Check for cracks or signs of deterioration in tanks or on slide gates and weir boxes.</li><li>2. Check air diffusers for cracks or plugging.</li></ol>

**TABLE 7.26**  
**Nos. 1 and 2 Digester Blowers**  
**Preventive Maintenance Schedule**

<b>Daily</b>
1. Check motors and blowers for excessive heat, noise, and vibration.
2. Check oil levels. Add oil as needed.
<b>Quarterly</b>
1. Drain oil from blower and replenish with fresh oil.

**TABLE 7.27**  
**No. 3 Digester Blowers**  
**Preventive Maintenance Schedule**

<b>Daily</b>
1. Check motors and blowers for excessive heat, noise, and vibration.
2. Check oil levels. Add oil to maintain oil level.
3. Check grease vent on blowers. Vents must be open at all times.
4. Clean blowers and motors to prevent buildup of grease and oil.
5. Clean up area as required.
<b>Every 500 Hours</b>
1. Grease drive end bearings of blowers every 500 hours with recommended lubricants.
<b>Every 1500 Hours</b>
1. Drain oil from blower, flush blower, and refill with recommended oil.

**TABLE 7.28**  
**Reciprocating Sludge Pumps**  
**Preventive Maintenance Schedule**

<b>Monthly</b>
1. Drain oil from gear drive box and replace with fresh oil.
2. Check operation for unusual noise, heat or vibration.
<b>Quarterly</b>
1. Adjust or replace packing as needed.
<b>Semi-Annually</b>
1. Drain oil from oil sumps and replenish with fresh oil.
2. Apply grease to all fittings and cams.

**TABLE 7.29**  
**Digested Sludge Pump Station**  
**Preventive Maintenance Schedule**

<b>Weekly</b>
1. Check pump for unusual noise, heat or vibration.
2. Check lubricant levels. Maintain between 40-50% full.
3. Use only manufacturer specified lubricant to avoid pump damage.

**TABLE 7.30**  
**Lime Stabilization Blowers**  
**Preventive Maintenance Schedule**

<b>Daily</b>
1. Check motors and blowers for excessive heat, noise, and vibration. 2. Check oil levels. Add oil to maintain oil level. 3. Check grease vent on blowers. Vents must be open at all times. 4. Check blowers and motors to prevent buildup of grease and oil. 5. Clean up area as required.
<b>Every 500 Hours</b>
1. Grease drive end bearings of blowers every 500 hours with recommended lubricants.
<b>Every 1500 Hours</b>
1. Drain oil from blower, flush blower, and refill with recommended oil.

**TABLE 7.31**  
**Backwash Holding Pumps**  
**Preventive Maintenance Schedule**

<b>Weekly</b>
1. Grease pump and shaft bearings.
<b>Monthly</b>
1. Lubricate motor grease fittings.
<b>Quarterly</b>
1. Remove and replace packing if needed.

**TABLE 7.32**  
**Plant Gates, Valves, and Sluice Gates**  
**Preventive Maintenance Schedule**

---

**Annually**

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1. Operate gates and valves in the plant and perform lubrication as recommended by manufacturer.
-

## CHAPTER 8

### STANDARD OPERATING PROCEDURES

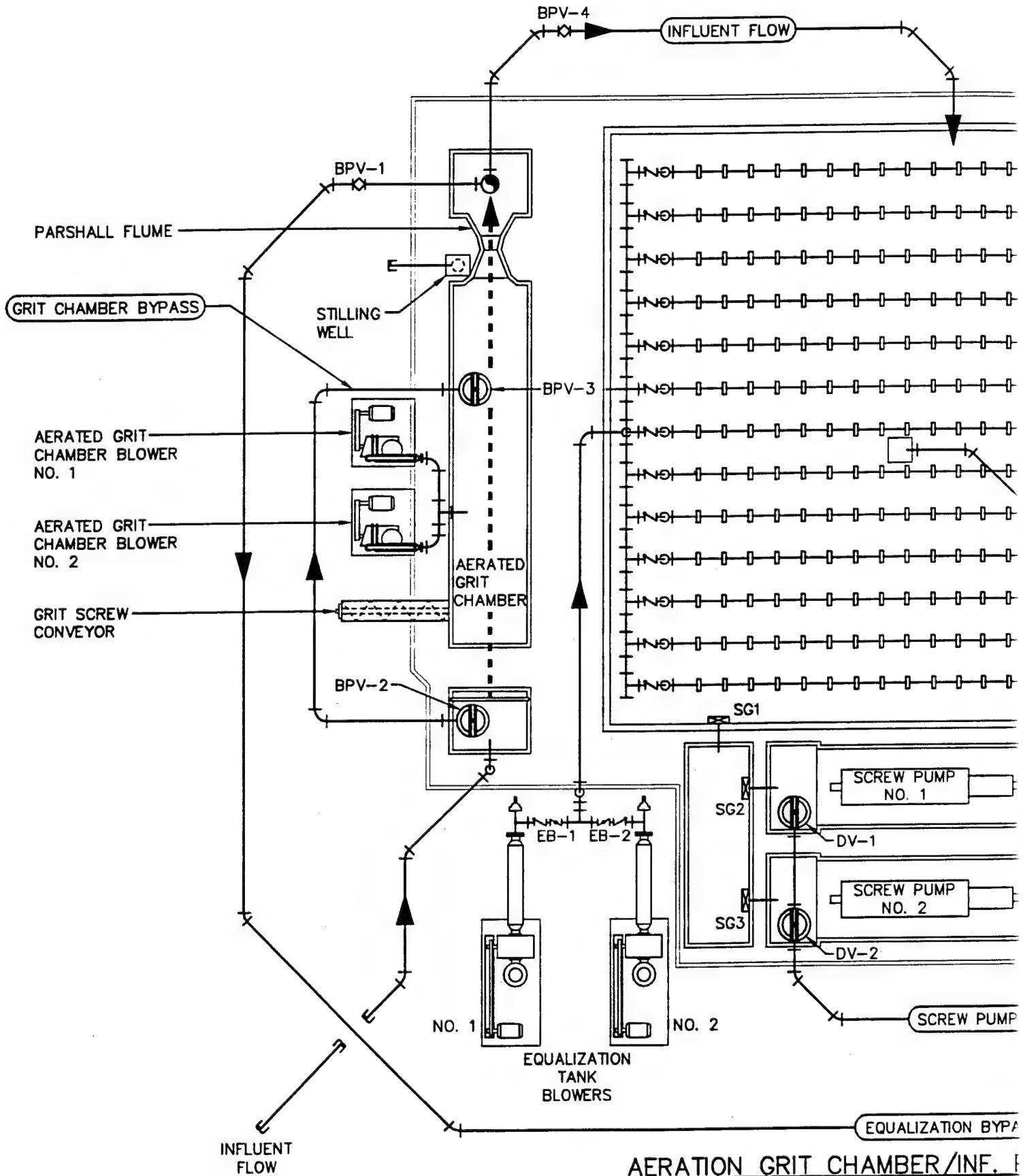
#### 8.1 INTRODUCTION

This chapter presents standard operating procedures (SOPs) for the Shaw AFB wastewater treatment plant. The procedures are presented in a tabular and checklist format so they can be removed, copied, and used in the field during operations.

The procedures should be read and understood before initiating operations of the various treatment systems. Also, daily O&M check sheets should be utilized for routine plant and lift station equipment monitoring. Vendor and manufacturer's literature should also be consulted as supplements to these procedures. Additionally, the preventive maintenance and laboratory sampling and analytical schedules contained in Chapters 7 and 4, respectively, should be consulted as needed. These SOPs are designed to aid the operator in the consistent and safe operation of the Shaw WWTP. They also can serve as documents to use in training new operators.

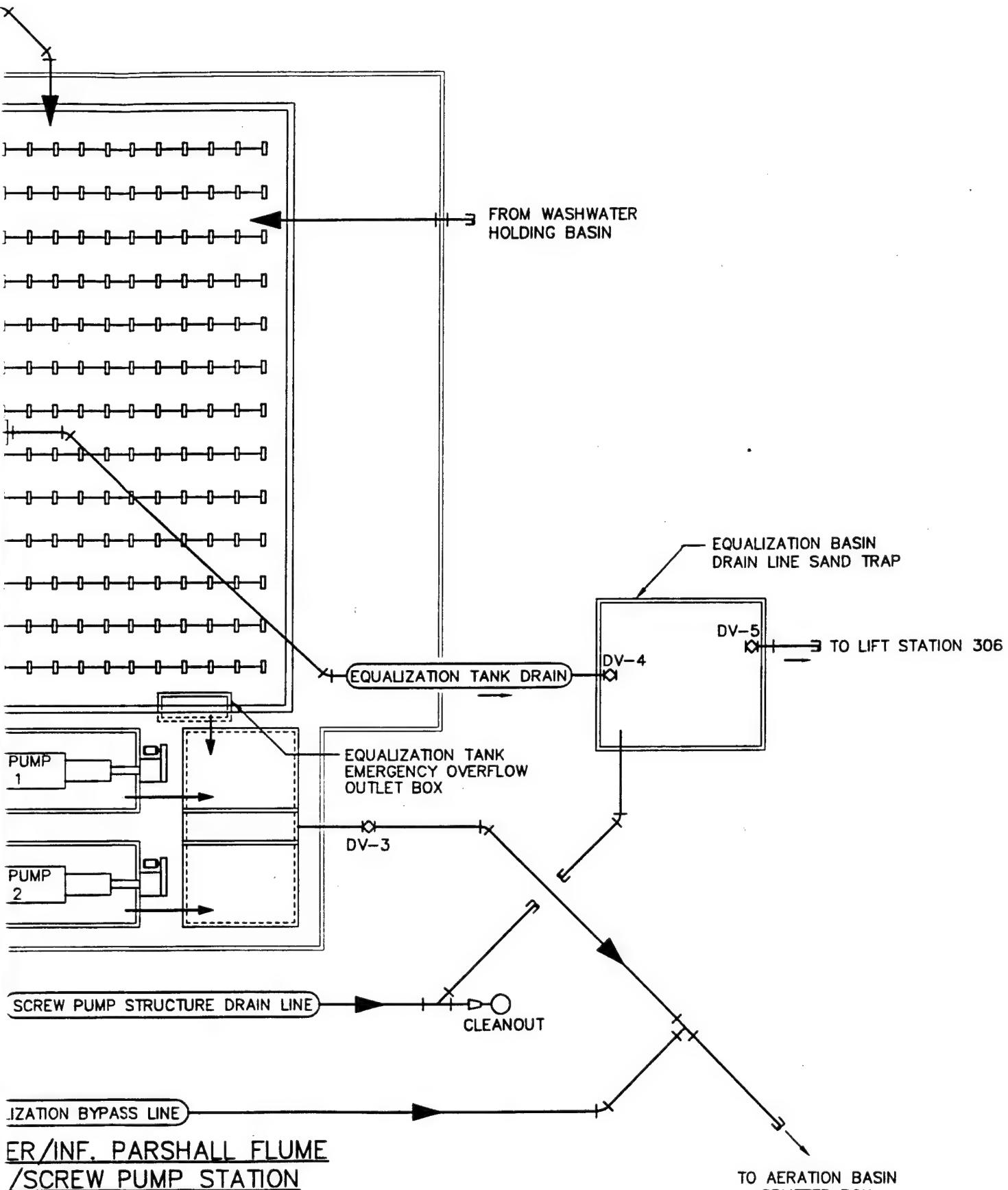
No operating procedures can be fully accurate without the input of the operating staff. Thus, when reviewing or using these procedures, the operations personnel should note any conflicts, discrepancies, or possible unsafe situations which are inherent in them. Corrections can then be instituted to insure that the procedures accurately describe the proper operating steps.

Figures 8.1 through 8.9 are provided to illustrate valve and gate locations for reference when using these procedures.



AERATION GRIT CHAMBER/INF.  
EQUALIZATION BASIN/SCREW  
VALVE AND EQUIPMENT

(1)



ER/INF. PARSHALL FLUME  
/SCREW PUMP STATION  
EQUIPMENT DIAGRAM

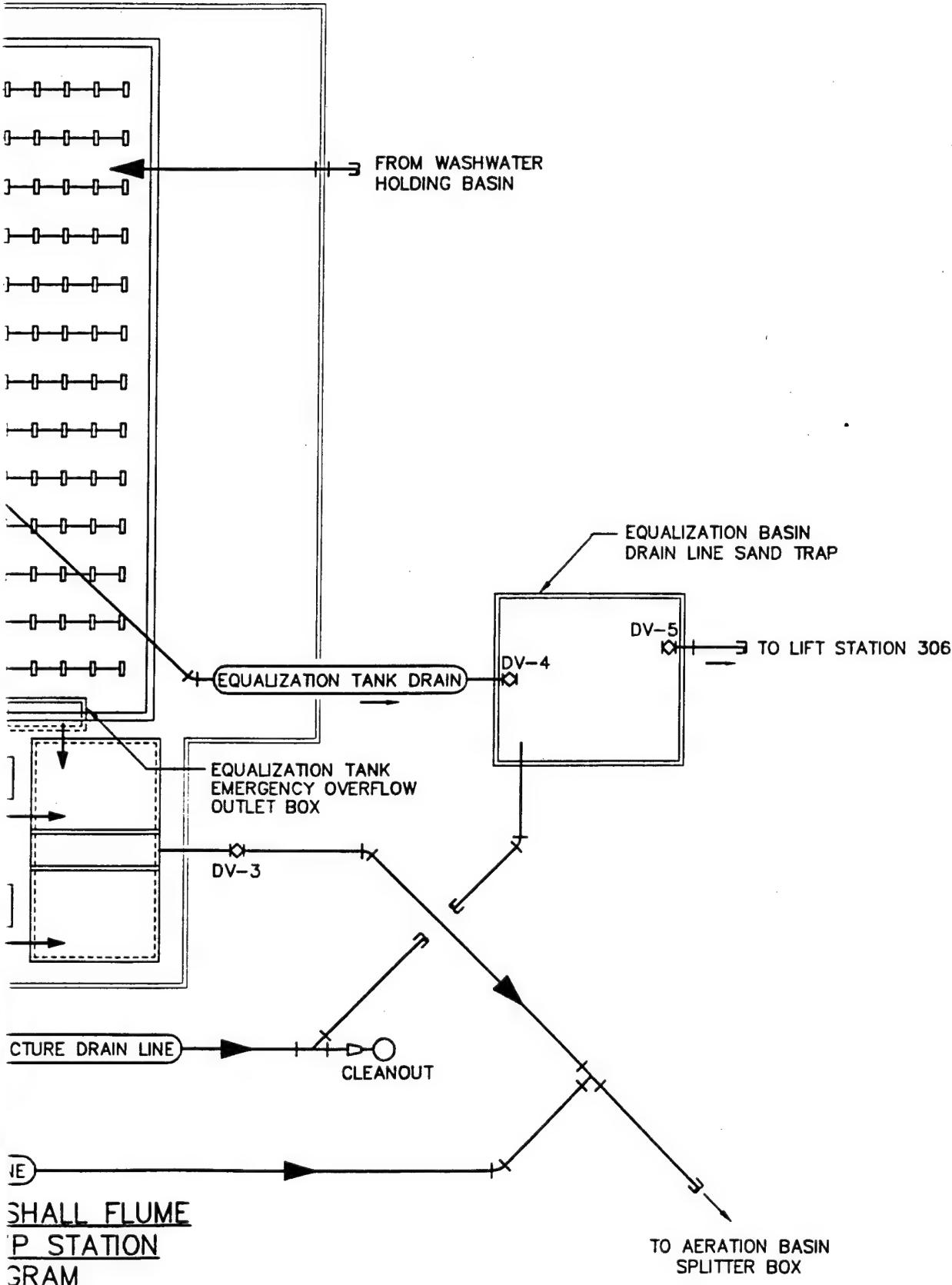


Figure 8.2

## SHAW AFB WWTP AERATION BASINS VALVE/EQUIPMENT DIAGRAM

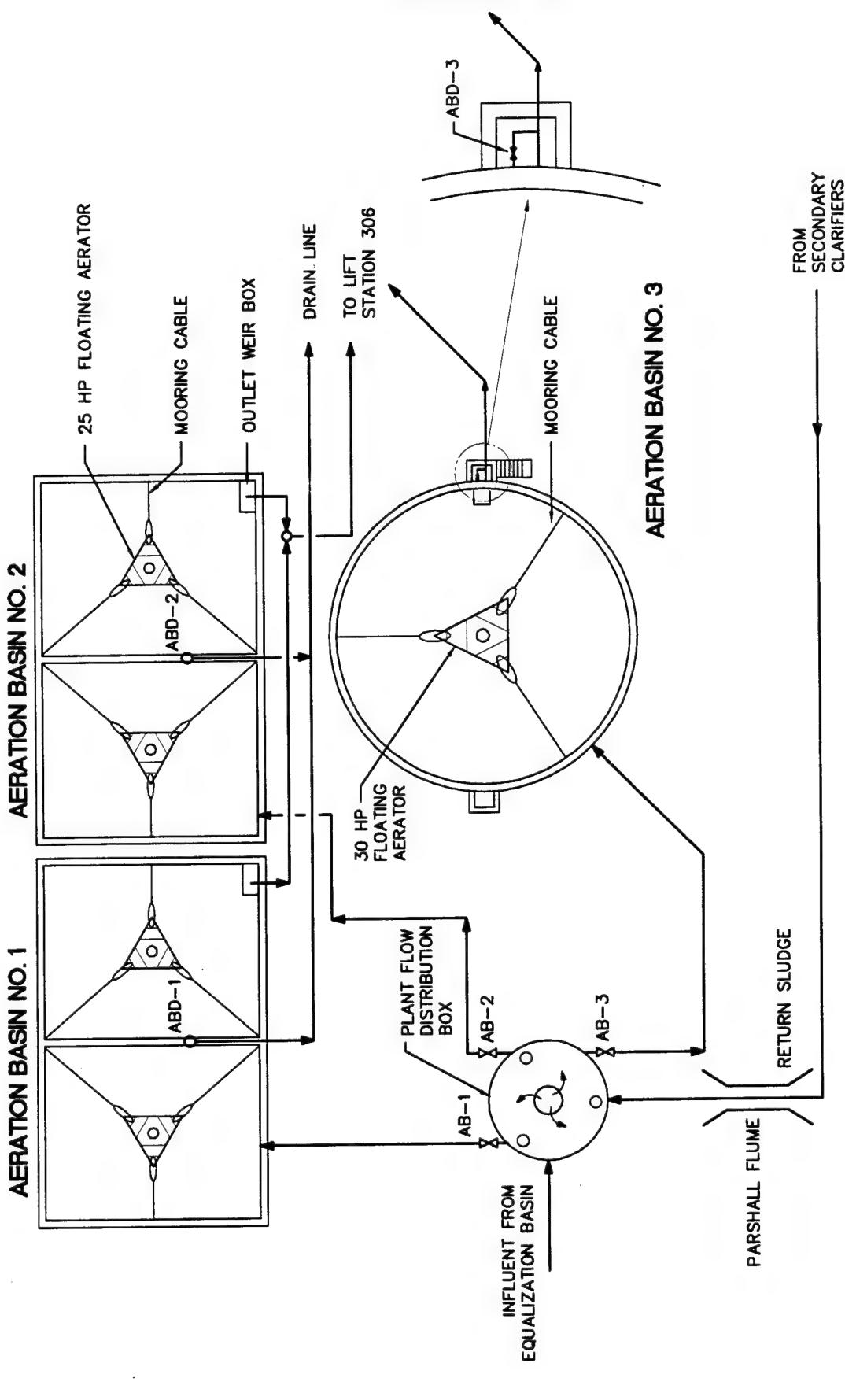
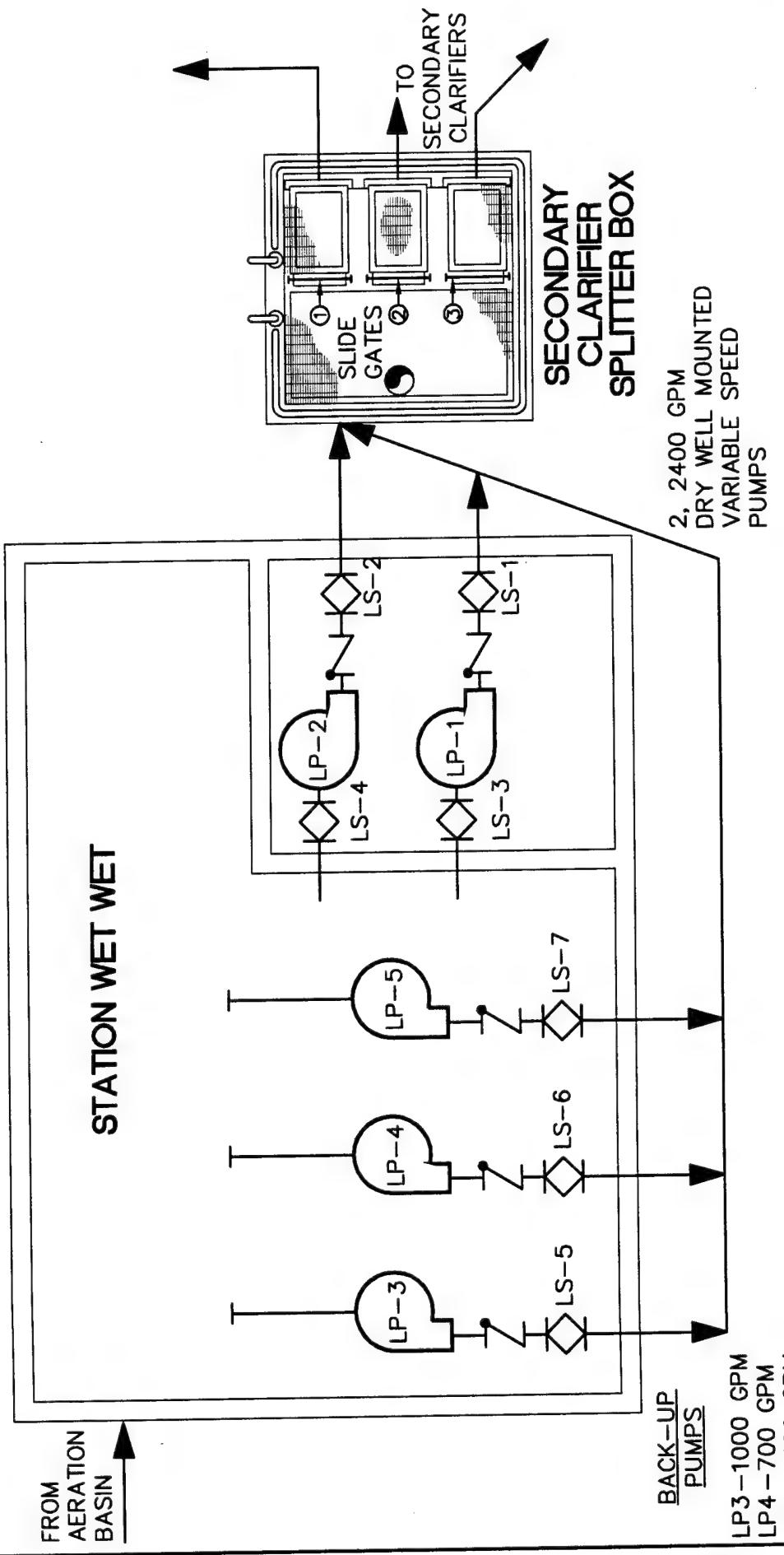
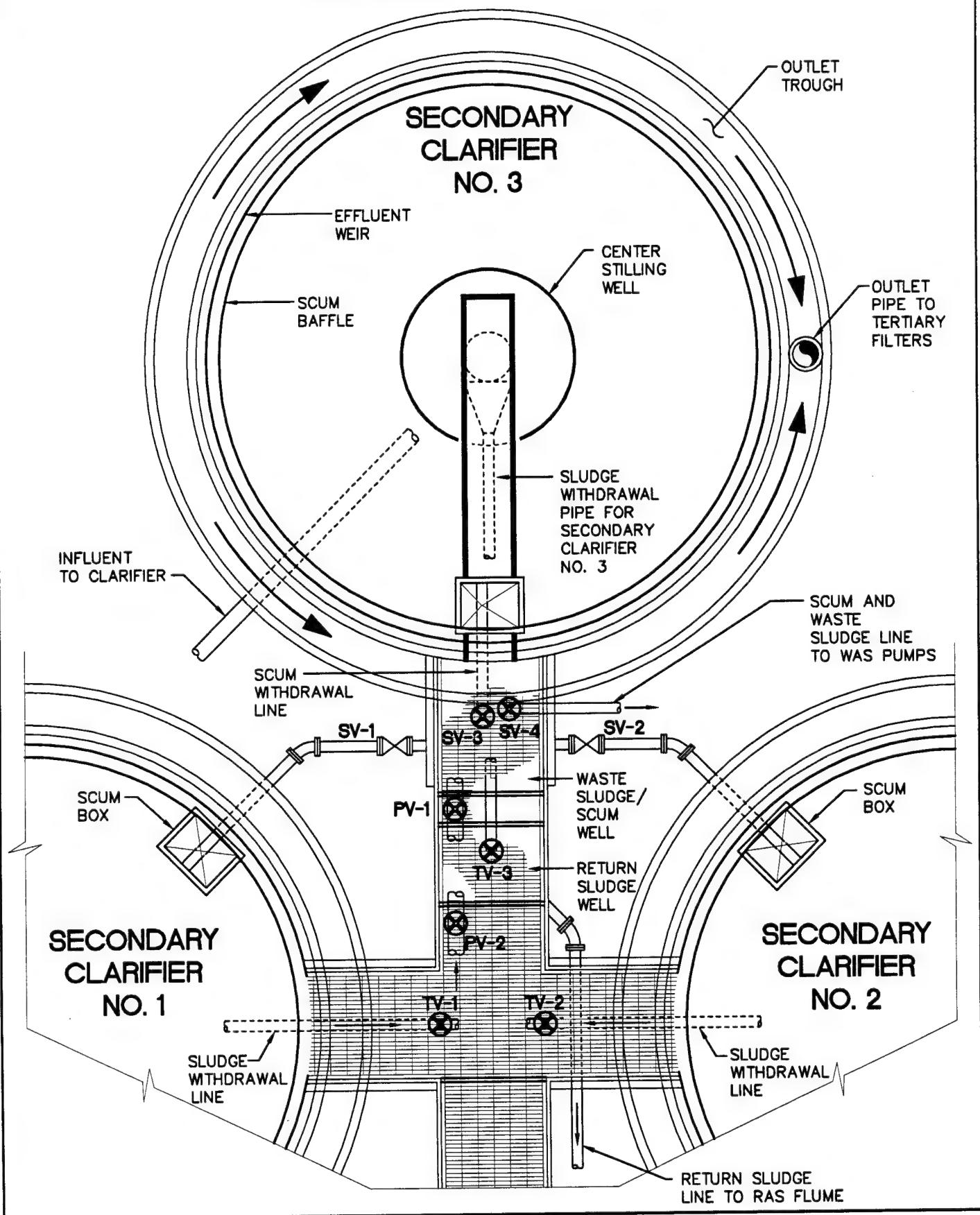


Figure 8.3

**SHAW AFB WWTP  
LIFT STATION 306 VALVE/EQUIPMENT DIAGRAM**



**SHAW AFB WWTP SECONDARY CLARIFIER  
VALVE/EQUIPMENT DIAGRAM**



**SHAW AFB WASTE SLUDGE  
PUMP STATION  
VALVE/EQUIPMENT DIAGRAM**

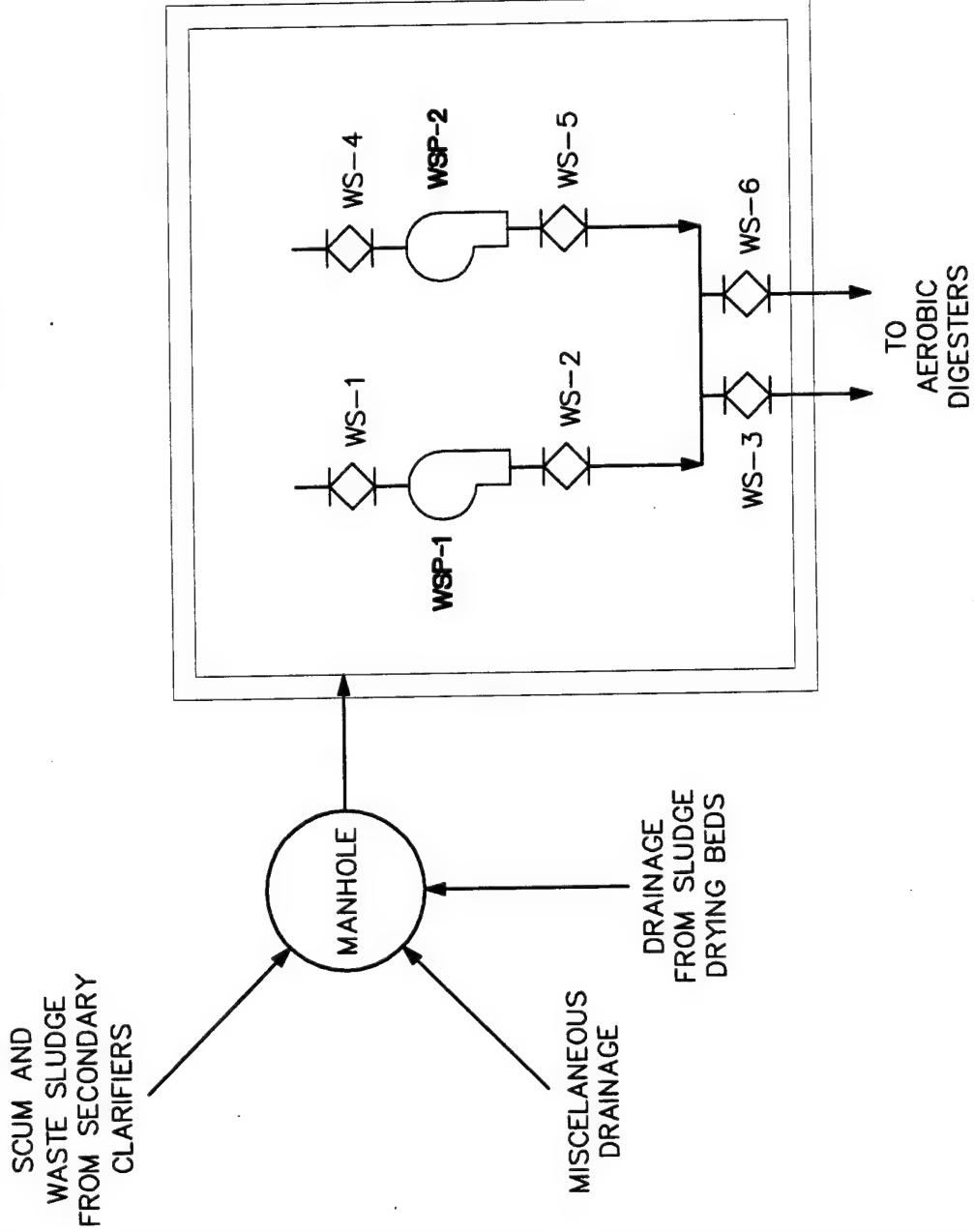


Figure 8.6

## SHAW AFB FILTERS PIPING AND VALVE DIAGRAM

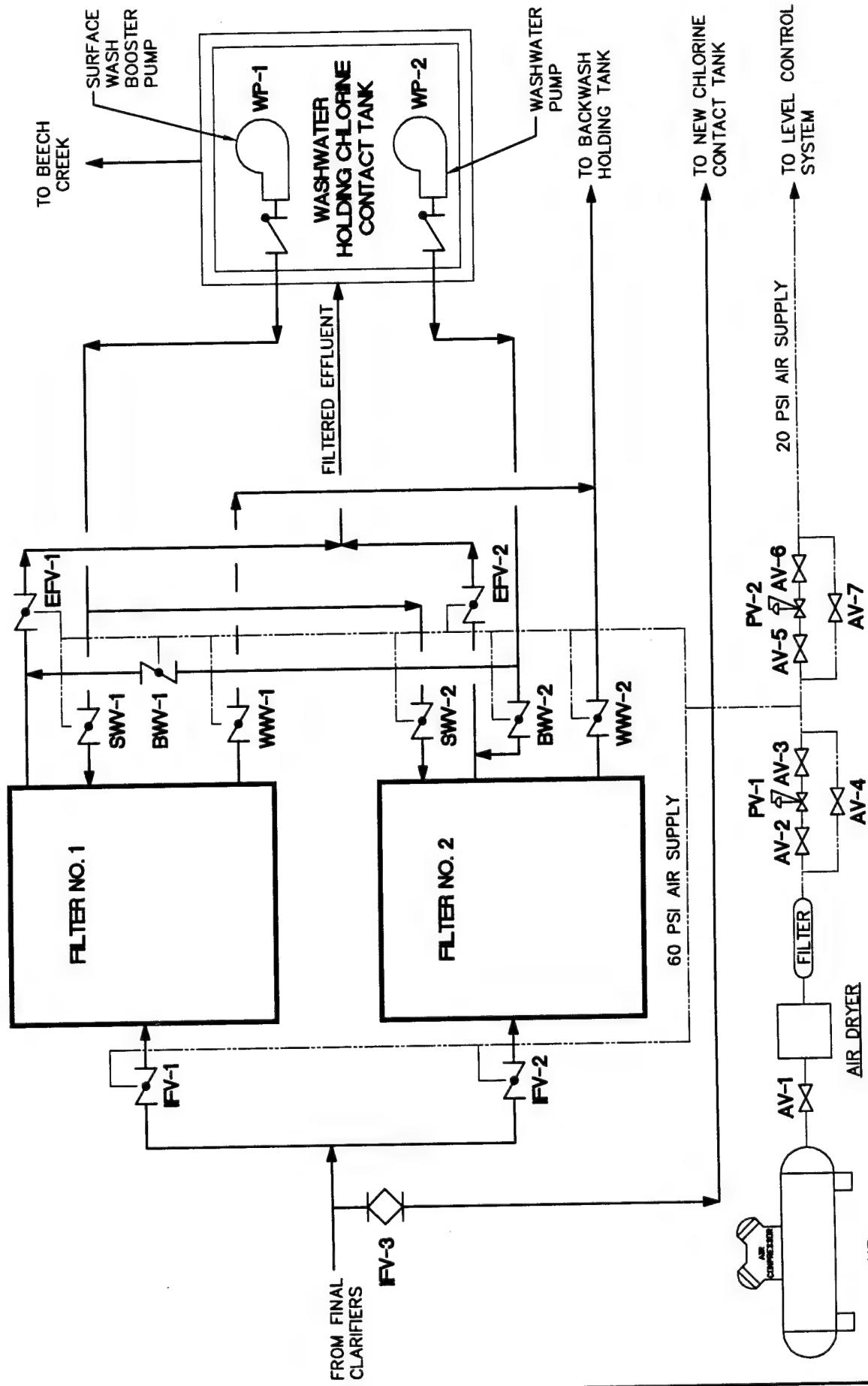
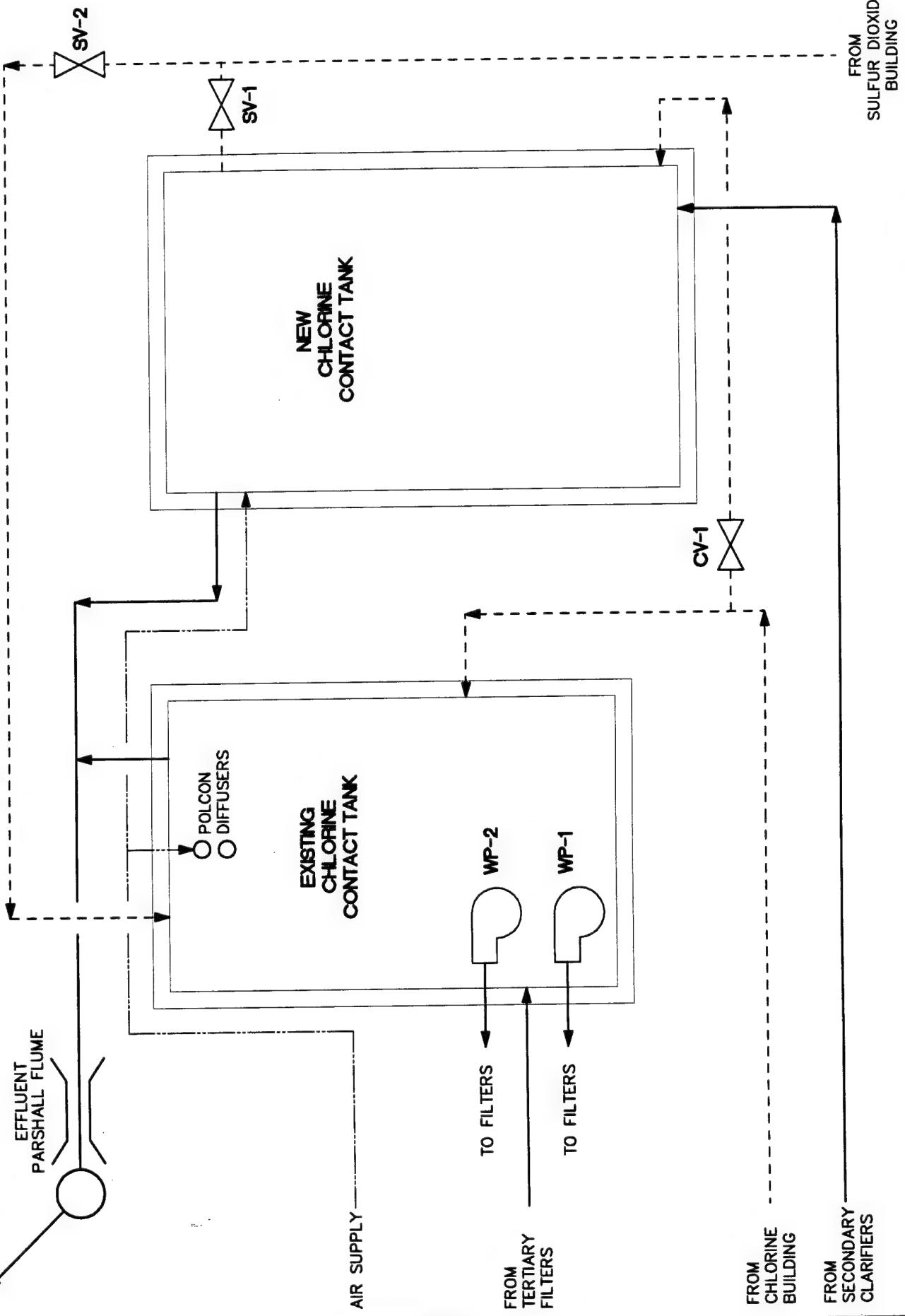
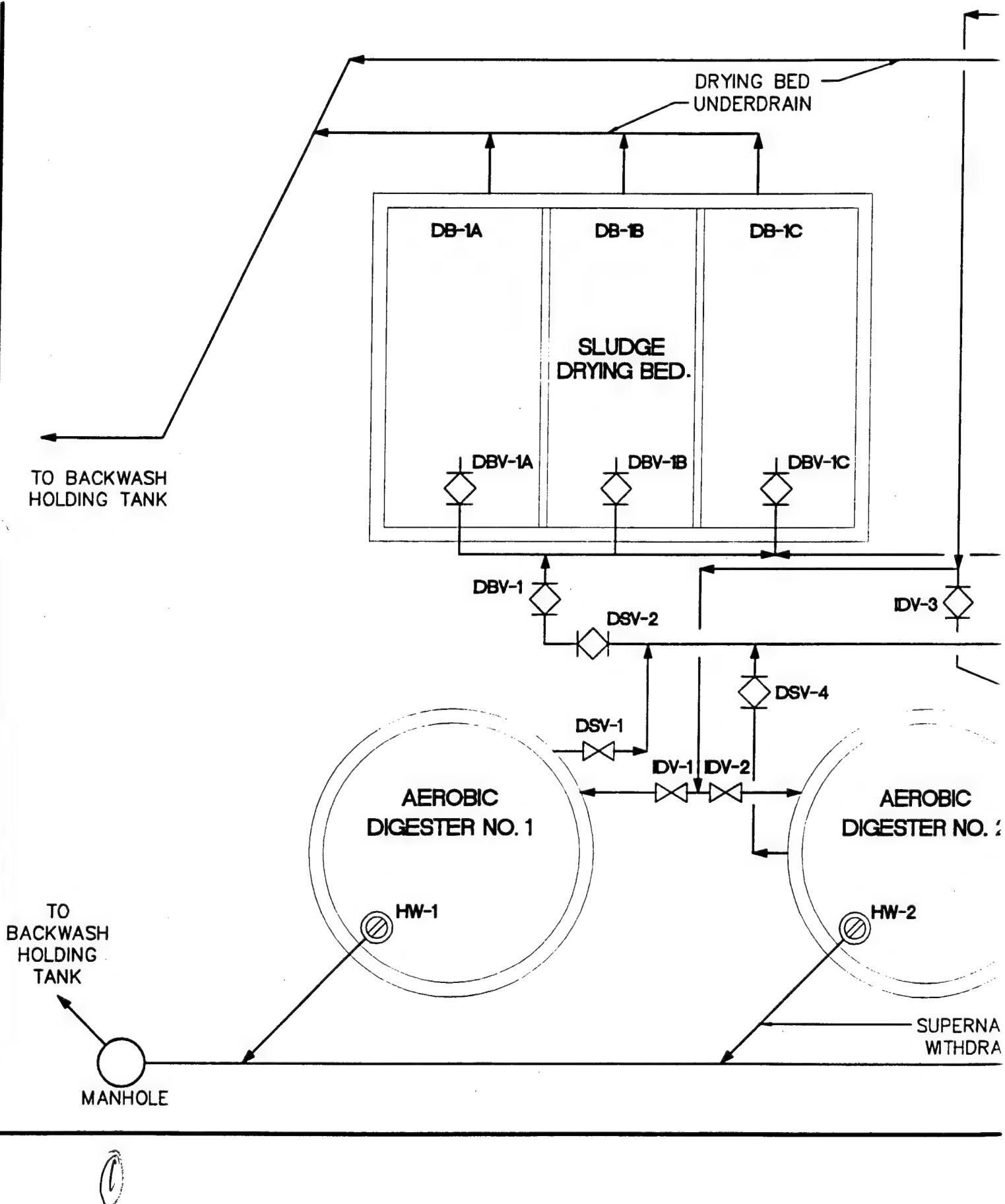


Figure 8.7

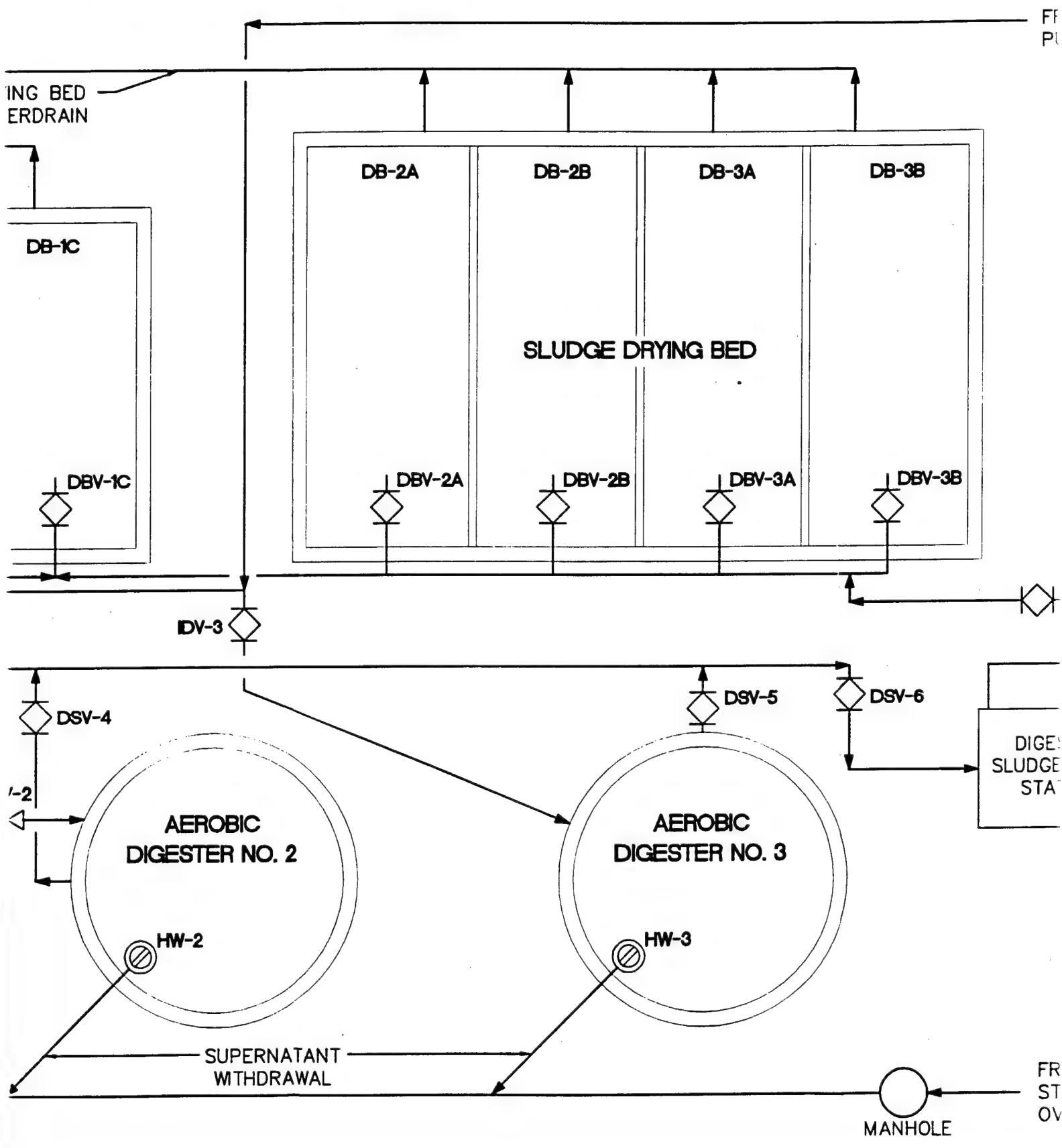
## SHAW AFB CHLORINE CONTACT TANKS PIPING AND VALVE DIAGRAM



SHAW AFB SLUD  
AND AEROBIC  
PIPING AND VA



**SHAW AFB SLUDGE DRYING BEDS  
AND AEROBIC DIGESTERS  
PIPING AND VALVE DIAGRAM**



**DRYING BEDS  
DIGESTERS  
E DIAGRAM**

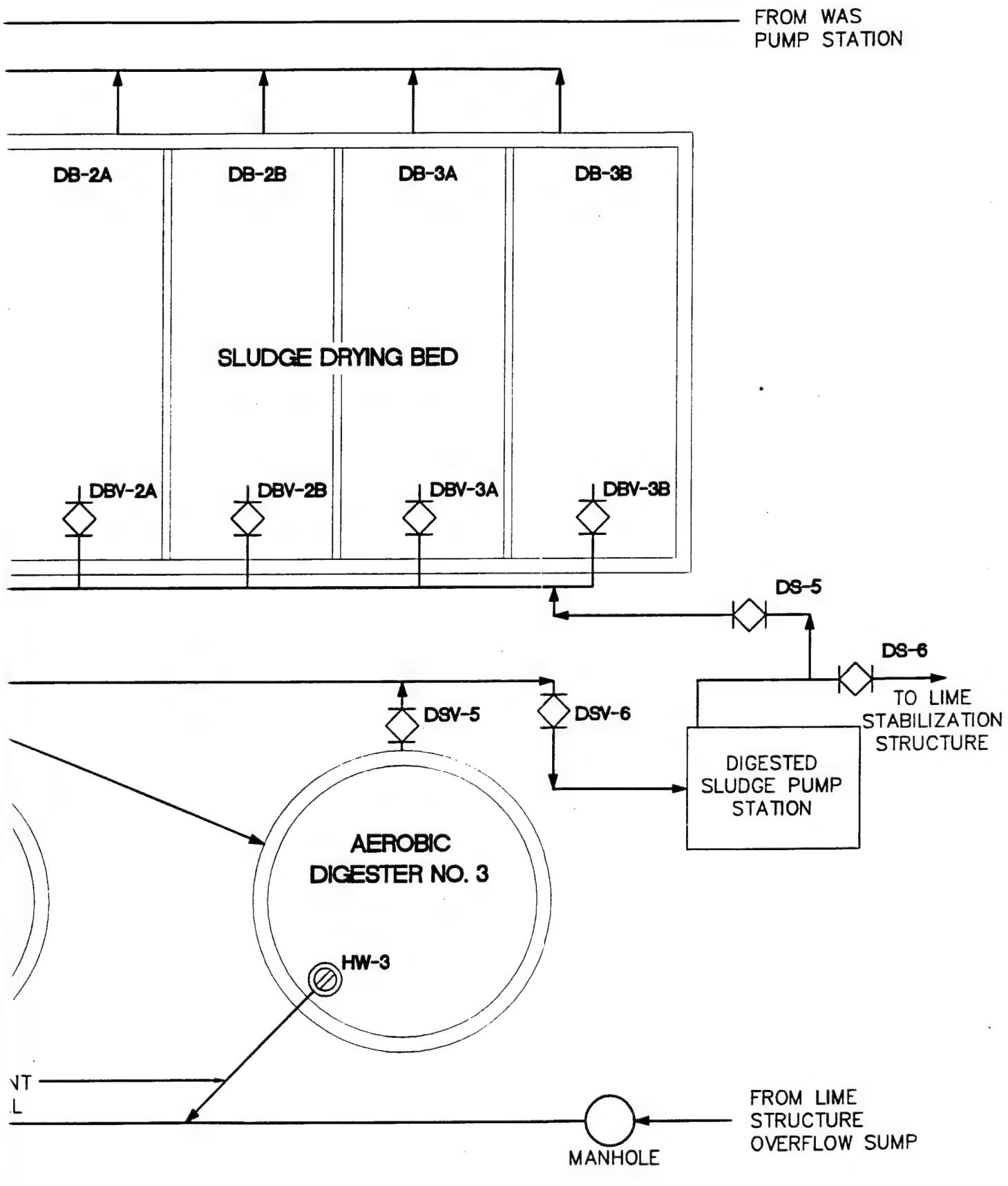
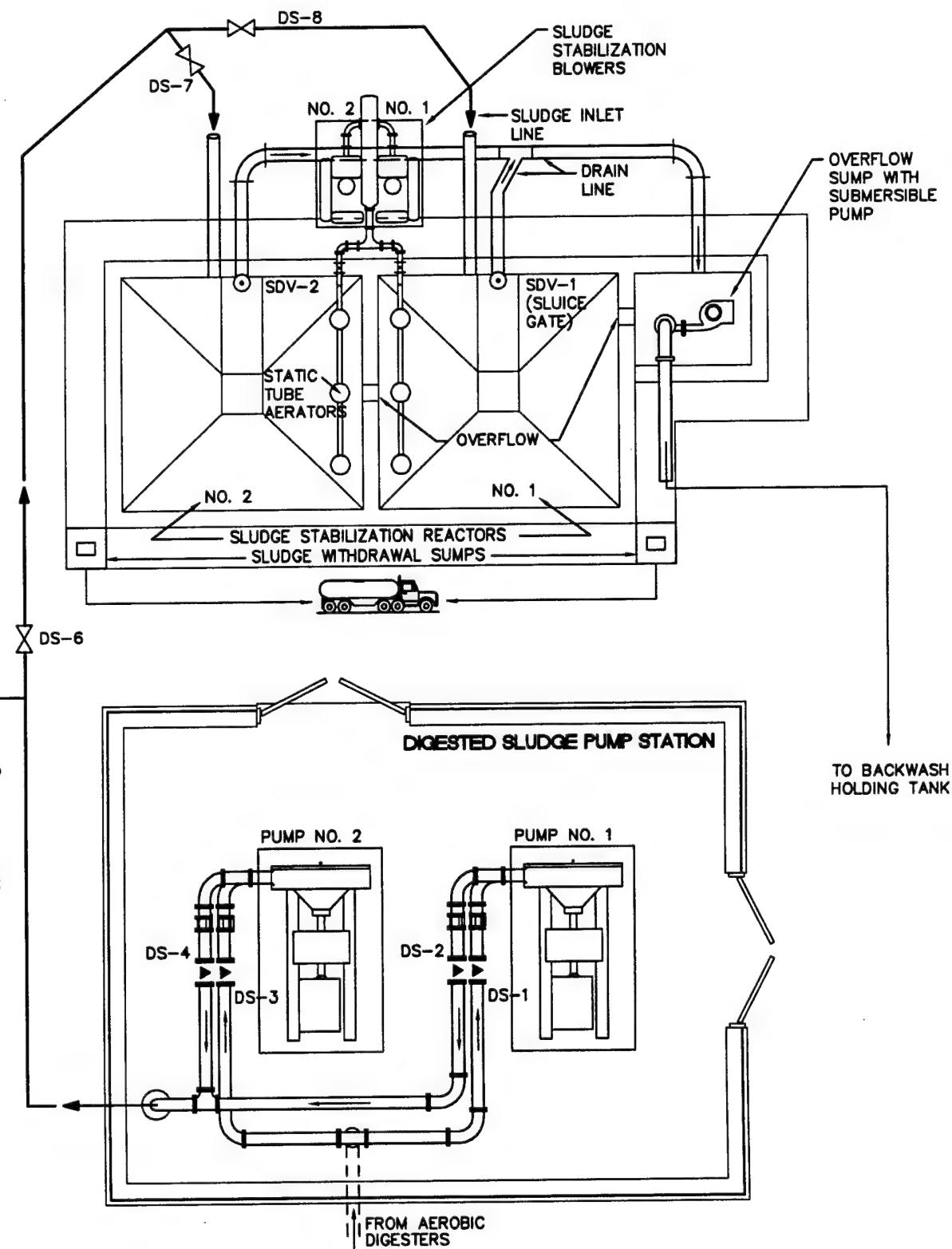


Figure 8.9

# SHAW AFB WWTP LIME STABILIZATION PROCESS AND DIGESTED SLUDGE PUMP STATION FLOW DIAGRAM



## 8.2 GENERAL STANDARDS OF PERFORMANCE

In addition to the standard operating procedures contained in Tables 8.1 through 8.10, the treatment plant operators should adhere to the following general standards of performance:

1. All incoming operators should confer with the operators on the previous shift. Special consideration should be given to operational changes made, equipment malfunctions, and out-of-the-ordinary conditions. The incoming operator will read logs and checksheets for proper operating conditions.
2. The incoming operators should immediately tour the treatment plant, observing all treatment equipment and processes.
3. Plant operators should maintain all records and logs current, neat and in ink. Unusual occurrences should be recorded in red ink to ensure proper notice by all personnel.
4. Plant operators should perform all required equipment adjustments, lubrication, and packing adjustments.
5. The operators should accomplish all sampling, analyses, pumping, and preventive maintenance as scheduled.
6. The operators should perform all necessary housekeeping to keep all areas neat and clean to enhance resource protection and safety.
7. The plant operators must report all unusual conditions to the WWTP superintendent and the incoming operator.
8. The plant operators must observe pertinent safety rules and regulations at all times.

**TABLE 8.1**  
**STANDARD OPERATING PROCEDURE**  
**PRELIMINARY TREATMENT STRUCTURES**

Procedure Step	Operator Checkoff
<u>Normal Operation - Grit System/Parshall Flume</u>	
1. Observe the influent flow stream; look for unusual colors, odors, floating solids, oil or grease, or any change in normal conditions. Note changes.	_____
2. Check operation of grit chamber blowers. Check for unusual noise, heat, or vibration. Check discharge pressure and position of discharge valve.	_____
3. Perform necessary preventive maintenance on blowers. Refer to Table 7.14.	_____
4. Observe bubble and roll pattern in aerated grit chamber.	_____
5. Observe operation and condition of collector chain and buckets during one complete revolution of system.	_____
6. Observe operation and condition of grit elevator and grit screw conveyor during one complete revolution. Observe amount of grit collected.	_____
7. Check operation of grit collection system drive motors. Check for unusual noise, heat, or vibration.	_____
8. Perform necessary preventive maintenance on grit collector system motors. Refer to Table 7.15.	_____
9. Check entire system for rust or corrosion. Note findings.	_____
10. Observe operation and calibration of influent flow meter. Observe flow through Parshall flume for unusual conditions.	_____
11. Valve settings for normal operation. <u>CLOSED</u> BPV-1 BPV-2 BPV-3	_____
12. Collect samples as required. See Chapter 4, Sampling Schedule.	_____
<u>To By-Pass Aerated Grit Chamber</u>	
1. Open the following mud valves:	
BPV-2	_____
BPV-3	_____

**TABLE 8.1 (continued)**  
**STANDARD OPERATING PROCEDURE**  
**PRELIMINARY TREATMENT STRUCTURES**

<b>Procedure Step</b>	<b>Operator Checkoff</b>
2. Stop grit chamber blowers.	_____
3. Stop grit collection system.	_____

Note: Refer to Figure 8.1 for valve/equipment diagram.

**TABLE 8.2**  
**STANDARD OPERATING PROCEDURE**  
**EQUALIZATION**

Procedure Step	Operator Checkoff								
<u>Normal Operation</u>									
1. Observe bubble and mix pattern in equalization basin. Look for dead spots or isolated areas of large bubbles and excessive mixing. Note observations and report to supervision.	_____								
2. Check level in basin. Observe if water is flowing from washwater holding basin.	_____								
3. Check operation of equalization basin blowers. Check for unusual noise, heat, or vibration. Check position of discharge valve and discharge pressure.	_____								
4. Perform necessary preventive maintenance on blowers. Refer to Table 7.13.	_____								
5. Valve and gate settings for normal operations are as follows: <table><tr><td><u>OPEN</u></td><td><u>CLOSED</u></td></tr><tr><td>EB-1 or EB-2</td><td>BPV-1</td></tr><tr><td>SG-1</td><td>DV-1</td></tr><tr><td>SG-2 or SG-3</td><td>DV-2</td></tr></table>	<u>OPEN</u>	<u>CLOSED</u>	EB-1 or EB-2	BPV-1	SG-1	DV-1	SG-2 or SG-3	DV-2	_____
<u>OPEN</u>	<u>CLOSED</u>								
EB-1 or EB-2	BPV-1								
SG-1	DV-1								
SG-2 or SG-3	DV-2								
6. Take samples as required. See Chapter 4 , Sampling Schedule.	_____								
<u>To By-Pass Equalization Basin</u>									
1. Open BPV-1 and close BPV-4.	_____								
2. Stop operation of screw pumps.	_____								
3. Close DV-3.	_____								
4. Do not stop air flow to equalization basin unless basin is drained.	_____								
<u>To Drain Equalization Basin</u>									
1. Open drain valves DV-4 and DV-5 in equalization basin sand trap.	_____								

Note: Refer to Figure 8.1 for valve/equipment diagram.

**TABLE 8.3**  
**STANDARD OPERATING PROCEDURE**  
**SCREW PUMP STRUCTURE**

Procedure Step	Operator Checkoff
<b><u>Normal Operation</u></b>	
1. Valve settings for normal operation: <b>OPEN                   CLOSED</b> SG-2 or SG-3      DV-1 DV-3                  DV-2	_____
2. Check screw pump controller in motor control room for proper settings. Record settings.	_____
3. Check position of sluice gate (SG-1 and SG-2) on operating pump(s). Adjust if necessary.	_____
4. Check pump and drive motor for unusual noise, heat, or vibration.	_____
5. Observe flow of water through screw pump.	_____
6. Perform necessary preventive maintenance on screw pumps, motors, lubrication system, and sluice gates. Refer to Tables 7.17 - 7.19	_____
<b><u>To Drain Screw Pump Structure</u></b>	
1. Stop operation of screw pumps.	_____
2. Valve settings for draining screw pump structure are as follows: <b>OPEN                   CLOSED</b> DV-1                  SG-1 DV-2                  DV-3	_____

Note: Refer to Figure 8.1 for valve/equipment diagram.

**TABLE 8.4**  
**STANDARD OPERATING PROCEDURE**  
**AERATION BASINS**

Procedure Step	Operator Checkoff
<b><u>Normal Operation</u></b>	
1. Ensure that all aeration basin flow distribution valves are open: AB-1 AB-2 AB-3	_____
2. Observe operation of floating aerators for proper alignment and balance. Clean debris from platforms and mooring cables as needed.	_____
3. Observe the mixed liquor in each aeration basin. Note the color, odor, and type of surface foam.	_____
4. Run dissolved oxygen (DO) tests using the field DO meter and probe. Maintain a dissolved oxygen content of 2.0 mg/l at all locations. If DO levels are below 2.0 mg/l, notify the plant supervisor.	_____
5. On a monthly basis, run a complete dissolved oxygen profile in the aeration basins.	_____
6. Collect samples for mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids (MLVSS), and 30 minutes settleable solids each day.	_____
7. Utilize MLSS and MLVSS data to analyze process parameters such as food to microorganism ratio (F/M) and sludge retention time (SRT) and to make appropriate process adjustments each day. Process data should be plotted onto trend charts.	_____
8. Calculate sludge wasting rates daily to maintain a SRT of between 20-22 days.	_____
9. Perform the required preventive maintenance on the aeration basins. Refer to Tables 7.20.	_____
<b><u>To Shut Down an Aeration Basin</u></b>	
1. Ensure that the correct aeration basin flow distribution valve is closed for aeration basin 1, 2 or 3 (AB-1, AB-3 or AB-3).	_____
2. Monitor as in normal operation except increase the frequency of DO measurement to twice per shift for the basins remaining in service.	_____
3. Open the appropriate aeration basin drain valve ABD-1, ABD-2, or ABD-3 and slowly drain contents to Lift Station 306. The basin must be drained slowly to prevent solids overloading of the secondary clarifiers and fouling of the tertiary filters.	_____
4. Closely monitor secondary clarifier effluent settleable solids and sludge blanket depth during the draining process. Make the necessary adjustments in the sludge return rates to reduce sludge blanket depths.	_____
5. Keep floating aerator(s) running until basin level is dropped to 1-2 feet from bottom.	_____

**TABLE 8.4 (Continued)**  
**STANDARD OPERATING PROCEDURE**  
**AERATION BASINS**

Procedure Step	Operator Checkoff
6. Finish draining basin and wash down all equipment and tank surfaces.	_____
<b><u>Cold Weather Operation</u></b>	
1. Increase MLSS concentrations by 15-20% beginning in late November. Slowly increase sludge retention time to 30 days through December.	_____
2. Alternate aerator operation in aeration basins No. 1 and No. 2 to avoid excessive D.O. levels (greater than 6.0 mg/l).	_____
3. Maintain mixing capability by keeping one aerator in service at all times.	_____

Note: Refer to Table 8.2 for valve/equipment diagram.

**TABLE 8.5**  
**STANDARD OPERATING PROCEDURE**  
**LIFT STATION 306**

Procedure Step	Operator Checkoff
<b><u>Normal Operation</u></b>	
1. Ensure the following suction/discharge valve/positions in the lift station:	
OPEN                                  CLOSED	
LS-1                                  LS-5	
LS-2                                  LS-6	
LS-3                                  LS-7	
LS-4	
2. Operate variable speed pump LP-1 or LP-2 to pace forward flow from the aeration basins to the secondary clarifiers.	
3. Manually alternate pumps LP-1 and LP-2 weekly.	
4. Check the operation of the pump station on each shift. Respond immediately to high wet well alarm.	
5. Check the pump that is running for unusual noise, vibration, or heat buildup in motor or bearings.	
6. Ensure proper housekeeping is maintained inside lift station. Clean up spills of water, lubricants, etc., in dry well.	
7. Perform required preventive maintenance on pumps. Refer to preventive maintenance schedules. See Table 7.1.	
8. Observe flow into the clarifier splitter box once per day.	
<b><u>Operating Backup Pumps</u></b>	
1. Ensure the discharge valve is open for the desired backup pump.	
LP-3                                  LP-4                                  LP-5	
LS-5                                  LS-6                                  LS-7	
2. Start desired backup pump.	
3. Follow Items 4-8 under normal operation	

Note: See Figure 8.3 for valve/equipment diagram.

**TABLE 8.6**  
**STANDARD OPERATING PROCEDURE**  
**SECONDARY CLARIFIERS**

Procedure Step	Operator Checkoff
<u>Normal Operation</u>	
1. Ensure all weir plates are in place in the secondary clarifier splitter box. (See Figure 8.3)	_____
2. Observe operation of the secondary clarifier drive units. Look for accumulations and check for unusual noises, vibrations, or abnormal operating temperatures of bearings and motor.	_____
3. Observe surface of clarifier for unusual accumulation of foam. Record observations and correlate to aeration basin operating conditions.	_____
4. Perform sludge blanket depth measurements using the sludge judge once per shift as a minimum. Use data to adjust RAS rates.	_____
5. Adjust RAS gravity-flow rates by adjusting the telescopic valves on the clarifier bridges (TV-1, 2 or 3). Lowering the telescopic valves increases the RAS rates. See Figure 8.4.	_____
6. Make sure that valve PV-2 is open to allow RAS to flow to the central RAS well and out to the RAS Parshall Flume.	_____
7. Perform DO measurements in clarifier effluent daily.	_____
8. Collect samples as required. See Chapter 4, Sampling Schedule.	_____
9. Perform required preventive maintenance. Refer to Table 7.21.	_____
<u>To Waste Sludge</u>	
1. Ensure that valve PV-1 is open to divert the RAS flow to the waste sludge/scum well.	_____
2. Open valve SV-4 to allow sludge to flow to the waste sludge pump station.	_____
3. Ensure that the suction and discharge valve for the selected WAS pump are open (see Figure 8.5):	_____
<u>WSP-1</u>	<u>WSP-2</u>
WS-1	WS-4
WS-2	WS-5
WS-3	WS-6
4. Open the selected digester inlet valve (IDV 1, 2 or 3). See Figure 8.8.	_____
5. Start the sludge pump and run for the calculated time for that day's required sludge wasting to the aerobic digesters.	_____
6. Turn off sludge pump, close valves SV-4 and PV-1 at the clarifiers.	_____

**TABLE 8.6 (Continued)**  
**STANDARD OPERATING PROCEDURE**  
**SECONDARY CLARIFIERS**

Procedure Step	Operator Checkoff								
7. Return to normal operation. Perform required preventive maintenance refer to Table 7.28.									
<b>To Remove Scum</b>									
1. Ensure that the scum valves which allow flow from the clarifier scum boxes to the waste sludge/scum well are open (SV-1, SV-2, SV-3).									
2. Open valve SV-4 to allow scum to flow to the waste sludge pump station.									
3. Ensure that the suction and discharge valve for the selected WAS pump are open: <table><tr><td><u>WSP-1</u></td><td><u>WSP-2</u></td></tr><tr><td>WS-1</td><td>WS-4</td></tr><tr><td>WS-2</td><td>WS-5</td></tr><tr><td>WS-3</td><td>WS-6</td></tr></table>	<u>WSP-1</u>	<u>WSP-2</u>	WS-1	WS-4	WS-2	WS-5	WS-3	WS-6	
<u>WSP-1</u>	<u>WSP-2</u>								
WS-1	WS-4								
WS-2	WS-5								
WS-3	WS-6								
4. Proceed as in sludge wasting above (Steps 4 - 7).									
<b>To Remove a Clarifier From Service</b>									
1. At the secondary clarifier splitter box, remove the weir plate for the unit to be taken out of service (weir plate 1, 2, or 3) and insert a slide gate.									
2. Slowly dewater clarifier throughout the return sludge telescopic valve (TV-1, TV-2, TV-3).									
3. Hose down clarifier when dewatered to remove sludge and scum deposits.									
4. Perform required inspections, repairs, and maintenance. Refer to Table 7.21.									
5. Resume flow into clarifier by replacing appropriate weir plate in the secondary clarifier splitter box.									

NOTE: See Figures 8.4, 8.5, and 8.8 for valve/equipment diagrams.

**TABLE 8.7**  
**STANDARD OPERATING PROCEDURE**  
**TERTIARY FILTERS**

Procedure Step	Operator Checkoff
<b><u>Normal Operation Both Filters in Operation</u></b>	
1. Ensure that the following valves are open: IFV-1 EFV-1 IFV-2 EFV-2	_____
2. Ensure that the following valves are closed: IFV-3 SWV-2 WWV-1 FWV-1 WWV-2 FWV-2 SWV-1	_____
3. Observe the operation of the filters: a) Observe level indicators at the console. b) Observe the filter effluent valves (EFV-1 and EFV-2) position (which corresponds directly to filter head losses).	_____
4. Collect samples as required. See Chapter 4, Sampling Schedule.	_____
5. Perform required preventive maintenance. Refer to Table 7.22.	_____
<b><u>Manual Backwash of Filter No.1</u></b>	
1. Close influent valve IFV-1.	_____
2. Drain down water level to media surface.	_____
3. Close effluent valve EFV-1.	_____
4. Start filter wash pump WP-2 and open waste valve WW-1.	_____
5. Open filter wash valve FWV-1.	_____
6. Start surface wash pump WP-1.	_____
7. Open surface wash valve SWV-1.	_____
8. Wash filters for 20-30 minutes or until backwash water is clear. Adjust wash time as needed.	_____
9. Close surface wash valve SWV-1 and stop surface wash pump WP-1.	_____
10. Close filter wash valve FWV-1 and stop filter wash pump WP-2.	_____
11. Close waste valve WWV-1.	_____
12. Open effluent valve EFV-1, then influent valve IFV-1.	_____
<b><u>Manual Backwash of Filter No.2</u></b>	
1. Close influent valve IFV-2.	_____

**TABLE 8.7 (Continued)**  
**STANDARD OPERATING PROCEDURE**  
**TERTIARY FILTERS**

Procedure Step	Operator Checkoff
2. Drain down water level to media surface.	_____
3. Close effluent valve EFV-2.	_____
4. Start filter wash pump WP-2 and open waste valve WWV-2.	_____
5. Open filter wash valve FWV-2.	_____
6. Start surface wash pump WP-1.	_____
7. Open surface wash valve SWV-2.	_____
8. Wash filters for 20-30 minutes or until backwash water is clear. Adjust wash time as needed.	_____
9. Close surface wash valve SWV-2 and stop surface wash pump WP-1.	_____
10. Close filter wash valve FWV-2 and Stop filter wash pump WP-2.	_____
11. Close waste valve WWV-2.	_____
12. Open effluent valve EFV-2 and influent valve IFV-2.	_____
<u>Normal Operation, Filter No. 1 in Operation</u>	_____
1. Ensure that the following valves are open: IFV-1 EFV-1	_____
2. Ensure that the following valves are closed: IFV-2            SWV-1 IFV-3            SWV-2 WWV-1            FWV-1 WWV-2            FWV-2 EFV-2	_____
3. Observe the operation of the filter: a) Observe level indicator at the console. b) Observe the filter effluent valve (EFV-1) position (which corresponds directly to filter head losses).	_____ _____
4. Collect samples as required. See Chapter 4, Sampling Schedule.	_____
5. Perform required maintenance on valves and valve operators. Refer to Table 7.22.	_____

**TABLE 8.7 (Continued)**  
**STANDARD OPERATING PROCEDURE**  
**TERTIARY FILTERS**

Procedure Step	Operator Checkoff
<u>Normal Operation, Filter No. 2 in Operation</u>	
1. Ensure that the following valves are open: IFV-2 EFV-2	
2. Ensure that the following valves are closed: IFV-1 SWV-1 IFV-3 SWV-2 WWV-1 FWV-1 WWV-2 FWV-2 EFV-1	
3. Observe the operation of the filter: a) Observe level indicator at the console.	
b) Observe the filter effluent valve (EFV-2) position (which corresponds directly to filter head losses).	
4. Collect samples as required. See Chapter 4, Sampling Schedule.	
5. Perform required maintenance on valves and valve operators. Refer to Table 7.22.	

Note: Refer to Figure 8.6 for valve/equipment diagram.

**TABLE 8.8**  
**STANDARD OPERATING PROCEDURE**  
**CHLORINATION/DECHLORINATION**

Procedure Step	Operator Checkoff						
<u>Normal Operation</u>							
1. Check chlorine and sulfur dioxide feed systems during each shift. Ensure correct feed rate at rotometer.	_____						
2. Check for chlorine and sulfur dioxide leaks at chlorinators and cylinder connections.	_____						
3. Record the chlorine and sulfur dioxide cylinder weight daily.	_____						
<u>To Operate Old Chlorine Contact Tank</u>							
1. Ensure that valve IFV-3 (Bypass valve) at the tertiary filter is closed.	_____						
2. Ensure the following valves are closed: CV-1 SV-1	_____						
3. Check chlorine residual of the contact basin hourly just upstream of the addition of sulfur dioxide. Make feed rate adjustments to maintain chlorine residual of 0.5-1.0 mg/l at the sampling point for adequate disinfection.	_____						
4. Ensure sulfur dioxide supply by opening valve SV-2.	_____						
5. Check chlorine residual at the effluent metering station hourly. Make sulfur dioxide feed rate adjustments to maintain chlorine residual of 0 - 0.1 mg/l.	_____						
6. Ensure that the air diffusing system is working properly.	_____						
7. Collect effluent samples as required. Refer to Chapter 4, Sampling Schedule.	_____						
8. Perform required preventive maintenance. Refer to Tables 7.23 and 7.24.	_____						
<u>To Operate New Chlorine Contact Tank (Filter Bypass)</u>							
1. Ensure the following valves at the tertiary filters are in the correct position: <table style="margin-left: 100px;"><tr><td><u>CLOSED</u></td><td><u>OPEN</u></td></tr><tr><td>IFV-1</td><td>IFV-3</td></tr><tr><td>IFV-2</td><td></td></tr></table>	<u>CLOSED</u>	<u>OPEN</u>	IFV-1	IFV-3	IFV-2		_____
<u>CLOSED</u>	<u>OPEN</u>						
IFV-1	IFV-3						
IFV-2							
2. Ensure the following valves are in the correct position: <table style="margin-left: 100px;"><tr><td><u>OPEN</u></td><td><u>CLOSED</u></td></tr><tr><td>CV-1</td><td>SV-2</td></tr></table>	<u>OPEN</u>	<u>CLOSED</u>	CV-1	SV-2	_____		
<u>OPEN</u>	<u>CLOSED</u>						
CV-1	SV-2						
3. Check chlorine residual of the contact basin hourly upstream of the addition of sulfur dioxide. Make feed rate adjustments to maintain chlorine residual of 0.5 - 1.0 mg/l at the sampling point for adequate disinfection.	_____						
4. Ensure sulfur dioxide feed by opening valve SV-1.	_____						

**TABLE 8.8 (Continued)**  
**STANDARD OPERATING PROCEDURE**  
**CHLORINATION/DECHLORINATION**

Procedure Step	Operator Checkoff
5. Check chlorine residual at the effluent metering station hourly. Make sulfur dioxide feed rate adjustments to maintain chlorine residual of 0 - 0.1 mg/l.	_____
6. Collect effluent samples as required. See Chapter 4.	_____
7. Perform required preventive maintenance. Refer to Tables 7.23 and 7.24.	_____

Note: Refer to Figure 8.7 for a valve/equipment diagram.

**TABLE 8.9**  
**STANDARD OPERATING PROCEDURE**  
**AEROBIC DIGESTERS AND SLUDGE DRYING BEDS**

Procedure Step	Operator Checkoff
<b><u>Normal Operation</u></b>	
1. Observe digesters, aeration patterns for uniformity and consistency.	_____
2. Observe digesters for any unusual color or odors, accumulation of foam or scum, and air leak noises.	_____
3. Take dissolved oxygen (DO) measurement in each unit daily to ensure DO is 2.0 mg/l or greater.	_____
4. Collect samples as required to determine percent reduction of volatile matter in the digester. Target reduction is 40%.	_____
5. Perform required preventive maintenance. Refer to Tables 7.25, 7.26 and 7.27 for preventive maintenance schedules.	_____
<b><u>To Draw Supernatant From Digesters</u></b>	
1. Discontinue feed to digester by closing the appropriate inlet valve. <u>For Digester No 1</u> <u>For Digester No.2</u> <u>For Digester No.3</u> IDV-1                          IDV-2                          IDV-3	_____
2. Discontinue aeration of the digester for 2-4 hours by shutting down the appropriate blower.	_____
3. Slowly lower the decanting weir box for the digester being supernated by turning the hand wheel as follows: <u>For Digester No 1</u> <u>For Digester No.2</u> <u>For Digester No.3</u> HW-1                            HW-2                            HW-3	_____
4. Observe supernatant quality to ensure that a minimum of solids are being withdrawn.	_____
5. Continue drawing supernatant to the lowest level possible by repeatedly lowering the decanting weir box.	_____
6. This procedure should be repeated each day that sludge is wasted to a digester and 8-12 hours of digestion have occurred. This will ensure maximum thickness of digested sludge and ensure maximum digester capacity for additional wasting.	_____
<b><u>To Draw Sludge to the Drying Beds</u></b>	
1. Turn off digester and decant as much liquid as possible as above.	_____
2. Isolate the digester to be withdrawn from by closing inlet valve (IDV-1, IDV-2, or IDV-3)	_____
3. Aerate the digester for 1-2 days to ensure stabilization of most recently fed sludge.	_____

**TABLE 8.9 (Continued)**  
**STANDARD OPERATING PROCEDURE**  
**AEROBIC DIGESTERS AND SLUDGE DRYING BEDS**

Procedure Step	Operator Checkoff
4. Sample the digester and analyze for volatile solids. Determine the percent reduction of volatile solids using the following formula:	
$P = \frac{(IN - OUT)}{IN - (IN \times OUT)} \times 100\%$ where: IN = % volatile solids in feed sludge OUT = % volatile solids leaving the digester P = % reduction in volatile solids	
5. Sludge from any of the three digesters can be wasted to any of the seven drying beds. Choose a drying bed to be used and open the corresponding digester sludge valve, header valve, and drying bed valve.	
Example: To draw sludge from digester No. 1 to drying bed 2A, open the following:	
<u>Digester Sludge Valve</u> <u>Header Valve</u> <u>Drying Bed Valve</u> DSV-1                          DBV-1                          DBV-2A DSV-2	
6. Draw sludge no more than 8-12 inches in any bed to facilitate the dewatering process.	
7. Close digester, header, and drying bed valves when finished.	
<u>To Pump Digested Sludge to Lime Stabilization Process</u>	
1. Turn off digester and supernatant as much liquid as possible, as above.	
2. Isolate the digester to be withdrawn from by closing inlet valve (IDV-1, IDV-2, or IDV-3)	
3. Aerate the digester for 1-2 days to ensure stabilization of most recent bed sludge.	
4. Sample the digester and analyze for volatile solids. Determine the percent reduction of volatile solids using the following formula:	
$P = \frac{(IN - OUT)}{IN - (IN \times OUT)} \times 100\%$ where: IN = % volatile solids in feed sludge OUT = % volatile solids leaving the digester P = % reduction in volatile solids	

**TABLE 8.9 (Continued)**  
**STANDARD OPERATING PROCEDURE**  
**AEROBIC DIGESTERS AND SLUDGE DRYING BEDS**

Procedure Step	Operator Checkoff								
5. Ensure the following valve positions in the digested sludge pump station:									
<u>To use pump no. 1</u>	<u>To use pump no. 2</u>								
<u>OPEN</u> <u>CLOSED</u>	<u>OPEN</u> <u>CLOSED</u>								
DS-1      DS-3	DS-3      DS-1								
DS-2      DS-4	DS-4      DS-2								
6. Ensure that the appropriate digester valves are in correct position for withdrawing digested sludge:									
<u>Digester No. 1</u>	<u>Digester No. 2</u>	<u>Digester No. 3</u>							
<u>OPEN</u> <u>CLOSED</u>	<u>OPEN</u> <u>CLOSED</u>	<u>OPEN</u> <u>CLOSED</u>							
DSV-1      DSV-2	DSV-4      DSV-1	DSV-5      DSV-1							
DSV-6      DSV-4	DSV-6      DSV-2	DSV-6      DSV-2							
DSV-5	DSV-5	DSV-4							
7. Ensure the following valves are in the correct position at the sludge stabilization reactors:									
<u>For Reactor 1</u>	<u>For Reactor 2</u>								
<u>OPEN</u> <u>CLOSED</u>	<u>OPEN</u> <u>CLOSED</u>								
DS-6      DS-5	DS-5      DS-6								
DS-8      DS-7	DS-7      DS-8								
8. Start the selected digested sludge pump and transfer sludge to the selected lime stabilization reactor.									
<u>To Remove a Digester From Surface</u>									
1. Follow one of the above procedures for withdrawing sludge to the drying beds or the lime stabilization process or a combination in order to empty the digester.									
2. Wash down all interior equipment in digester and perform complete inspection of interior.									
3. Perform required preventive maintenance. Refer to Table 7.25, 7.26 and 7.27.									

Note: Refer to Figures 8.8, and 8.9 for a valve/equipment diagrams.

**TABLE 8.10**  
**STANDARD OPERATING PROCEDURE**  
**LIME STABILIZATION PROCESS**

Procedure Step	Operator Checkoff			
<b>Pumping Sludge to Reactors</b>				
1. Ensure the following valve positions in the Digested Sludge Pump Station:				
<u>TO USE PUMP NO. 1</u>	<u>TO USE PUMP NO. 2</u>			
<u>OPEN</u> <u>CLOSED</u>	<u>OPEN</u> <u>CLOSED</u>			
DS-1              DS-3	DS-3              DS-1			
DS-2              DS-4	DS-4              DS-2			
2. Ensure that the appropriate digester valves are in correct position for withdrawing digested sludge:				
<u>DIGESTER NO. 1</u>	<u>DIGESTER NO. 2</u>	<u>DIGESTER NO. 3</u>		
<u>OPEN</u> <u>CLOSED</u>	<u>OPEN</u> <u>CLOSED</u>	<u>OPEN</u> <u>CLOSED</u>		
DSV-1              DSV-2	DSV-4              DSV-1	DSV-5              DSV-1		
DSV-6              DSV-4	DSV-6              DSV-2	DSV-6              DSV-2		
DSV-5	DSV-5	DSV-4		
3. Ensure the following valves are in the correct position at the sludge stabilization reactors:				
<u>FOR REACTOR 1</u>	<u>FOR REACTOR 2</u>			
<u>OPEN</u> <u>CLOSED</u>	<u>OPEN</u> <u>CLOSED</u>			
DS-6              DS-5	DS-6              DS-5			
DS-8              DS-7	DS-7              DS-8			
4. Start the selected digested sludge pump and transfer sludge to the selected reactor.				
5. Monitor reactor level; turn off pump when reactor is filled. Do not allow level in reaction tanks to reach the pump auto shut-down level during fill cycle.				
6. If attempting to empty a full digester, one drying bed must be utilized prior to filling the reaction tanks.				
<b>Lime Addition to Digested Sludge</b>				
1. When the level of sludge in the stabilization reactor is half full, start the appropriate sludge stabilization blower.				
2. Continue to aerate the sludge through the stabilization cycle.				
3. Begin lime addition to the stabilization reactor using the lime system motor control panel. Refer to Items 4-10 below.				
4. Ensure that all circuit breakers are in the "ON" position.				
5. Place the circuit breaker at motor control panel CP1 in the "ON" position.				
6. Turn the control power switch to the "ON" position.				
7. Place the hand-off-auto switches for the equipment to be operated in the "HAND" position. (Exhaust fan, shank, bin vent, vibrator and feeder)				
8. Start the lime feeder and set the feed control selector as required by pulling the green power button.				

**TABLE 8.10 (Continued)**  
**STANDARD OPERATING PROCEDURE**  
**LIME STABILIZATION PROCESS**

Procedure Step	Operator Checkoff
9. Samples of the sludge from the reactor tanks should be taken periodically and analyzed for pH. Lime addition should continue until the pH of the sludge is raised to 12.0 at a minimum.	_____
10. After sludge pH in the reactor reaches 12.0, turn the lime feeder off.	_____
11. Hold sludge in the reactor tank for 2 hours. Take another pH to ensure that pH has been maintained. Add additional lime if needed and begin 2-hour holding time again.	_____
<b><u>Removing Sludge from the Stabilization Process</u></b>	
1. Maintain sludge blower operation during draining of reactor tank until level is at the static tube aerator.	_____
2. Immerse the flexible hose coupling from the pump to the sludge transport truck into the reaction tank to be emptied.	_____
3. Make sure the vent pipe on the top of the truck is open.	_____
4. Energize the pump and pump sludge into the tank truck.	_____
5. Transport sludge loads to the land application site until the sludge sump and reactor tank(s) are emptied.	_____
6. Perform required preventive maintenance. Refer to Tables 7.29 and 7.30.	_____

NOTE: Refer to Figures 8.8 and 8.9.

## **CHAPTER 9**

### **RECORDS AND REPORTING**

#### **9.1 RECORDS AND REPORTING**

##### **9.1.1 Daily Operating Logs**

A comprehensive record-keeping system is essential to the operation of the Shaw AFB WWTP. Daily operating records are the central component of any record-keeping system.

Daily observation of all components in the WWTP system is necessary to ensure continued successful operation. The operators should utilize both a journal type logbook and a plant operational log.

The plant operational log contains routine information that is entered by each shift. All shifts are responsible for checking off and recording the following data:

- Bar screen rakings.
- Sludge withdrawn from digester.
- Digester supernatant withdrawn.
- Shift maximum influent/effluent pH.
- Flow meter readings from each shift.
- Chlorine usage and chlorine residuals.
- Sulfur dioxide.
- Lime usage.
- Aeration basin operating conditions.
- Secondary clarifier operating conditions.
- Personnel on duty.
- Equipment problems and unusual operating conditions.
- Lift station operating conditions.

### **9.1.2 Monthly Operating Logs**

The wastewater treatment plant operators are required to prepare monthly operating logs, specifically Air Force forms 1462, Water Pollution Control Utility Operating Log (General), and 1463 Water Pollution Control Plant Operating Log (Supplementary). Information required for these forms is drawn from daily plant operating logs and laboratory data sheets. Some of the important data required for these logs include the following:

- Influent temperature
- Influent pH
- Primary clarifier effluent pH
- Plant influent settleable solids
- Plant effluent settleable solids
- Plant effluent DO
- Plant effluent pH
- Chlorine residual
- Plant flow
- Cl<sub>2</sub> weight, pounds used.

### **9.1.3 Monthly Reports to Regulatory Agencies**

Under regulatory requirements, the WWTP operators are required to generate monthly self-monitoring reports to the State of South Carolina. Data from the reports is entered on the Operation Monitoring Report by the Supervisor of Water and Waste. The reports are then submitted to the Base Environmental Compliance Chief for review and approval.

### **9.1.4 Laboratory Worksheets**

The NPDES Permit requires that specific laboratory records (benchesheets) be maintained as part of the WWTP's self-monitoring program. These records provide the basis and validity for all analytical data produced and reported. Examples of laboratory worksheets are provided in Appendix A. These worksheets should be periodically updated to reflect regulatory changes.

### **9.1.5 Sludge Disposal Records**

A record of the quantity of sludge disposed of should be maintained for permit and operational documentation. Generally, the quantity of sludge produced by the wastewater treatment plant should be equal to the quantity disposed of. A record of sludge applied to the land treatment site should be maintained. This record should include a map with numbered plots. A weekly and cumulative record of the gallons and pounds of dry sludge applied to each plot should be kept.

## CHAPTER 10

### NONDOMESTIC DISCHARGES

#### 10.1 NONDOMESTIC DISCHARGES

In addition to the domestic wastewater treated at the Shaw AFB WWTP, a number of nondomestic discharges contribute to the load on the plant. Discussions with base personnel identified a number of sites where industrial waste could emanate and have an adverse impact on the wastewater treatment plant.

##### 10.1.1 Sources of Nondomestic Discharges

Based on discussions with plant personnel and flight line maintenance shop personnel, five potential nondomestic wastewater sources were identified as the Base which could have an impact on the WWTP if discharges from these areas reached the sanitary sewer system. Each of these sources has been visited by representatives of the WWTP staff to ascertain if waste handling practices present potential problems. These facilities are as follows:

- Base Photo Shop
- Electro/Environmental Shop
- Fuel Tank Maintenance Shop
- Aerospace Ground Equipment (AGE) Shop
- Corrosion Control Shop

The Photo Shop creates X-ray images of aircraft parts to detect metal stress. The development of film images takes place at another location. Liquid waste generating activities at the Photo Shop are all associated with the penetrant line. Three processes are undertaken. Aircraft parts are immersed in penetrant solution and rinsed, the parts are then cleaned with an emulsifier, and finally they are placed in a developer bath. Rinse water from this operation flows to the sanitary sewer. When the 500 gallon tanks of penetrant, emulsifier, and developer are spent, they are hauled off-site by a contract waste hauler. This area represents a potential threat to the WWTP. The rinse water is very low in volume and is probably inconsequential, but if the baths were to be released to the sewer, the plant would be severely affected. The penetrant is a hydrocarbon base green liquid that would have a strong odor of fuel or oil. The emulsifier is an ethylene

glycol product that is a dark pink and has a tendency to foam. Its purpose is to clean excess penetrant from the aircraft parts. It is not known what the effects of this solution would have at the WWTP if discharged. The developer is a sodium chromate, clear yellow solution that if discharged in a large quantity would have a serious toxic effect on the WWTP. It is mixed at a ratio of 1 pound per gallon. This shop should be closely monitored. Records should be examined periodically to ensure waste handling practices are being conducted properly.

The Fuel Tank Maintenance Area is included here due to the potential for fuel from this area reaching the sanitary sewer system. As its name implies, this shop inspects and repairs fuel tanks. Fuel is emptied from the tanks and any spilled fuel that is not contained is discharged to an oil/water separator. The oil/water separator is equipped with a pump that pumps oil accumulated in the separator to a storage tank. The pump is controlled by an interface probe, or float, which detects liquid level in the separator.

The Aerospace Ground Equipment (AGE) Maintenance shop is also included because of the potential for oily wastes associated with equipment maintenance to reach the sanitary sewer system. All waste oil is placed into a waste oil holding tank which, is serviced by a contractor monthly. Spills in the AGE maintenance area and wastewater from the AGE washrack flow to an oil/water separator.

The Electro/Environmental Shop which services both lead acid and nickel-cadmium (NiCd) batteries is included here because of its potential to discharge wastewaters with high metals content and extremes in pH. The Lead-Acid battery shop performs small neutralizations and occasionally has wash water clean up and disposal. Broken batteries which are brought in for service are taken to DMRO for disposal off-site by a hazardous waste contractor. The NiCd battery shop is less of a potential problem to the WWTP than the Lead-Acid shop. The NiCd batteries are sealed and open cells occur rarely, and when that does occur, they are disposed of by DMRO.

The Corrosion Control Shop historically had the potential to create problems at the WWTP but, at present, this is a dry operation. The usual chemical stripping of aircraft parts that takes place in corrosion control has been replaced by a glass bead blasting operation. There are no drains within the stripping and painting areas. There is a contained storage area outside the shop where solvents are stored. The shop maintains a

spill kit in the event of a solvent spill. It does not appear, at present, that the corrosion control area represents a significant potential problem for the WWTP.

Although there appears to be a small potential for industrial waste entering the sanitary sewer system, no definitive conclusions can be reached with regard to impact by industrial wastewater on the WWTP. Plant personnel have indicated that discharges from on-base have created problems with WWTP operation in the past. A case in point is the plant upset that occurred in February 1994. Plant personnel indicated that an unknown substance entered the plant that had a chemical odor and created 3 feet of foam in the equalization basin. Investigations into the source of this discharge were not successful. It appears that a more thorough, systematic industrial survey should be performed on the base to ensure that all sources of industrial waste and waste handling practices are identified. From this type of information, a contingency plan for identifying and responding to industrial wastewater problems at the WWTP can be developed.

#### **10.1.2 Importance of Pretreatment Programs for Nondomestic Discharges**

Pretreatment is any operation or series of operations that change the characteristics of a nondomestic discharge to make it more acceptable for subsequent treatment and disposal at a wastewater treatment facility. Pretreatment programs are often necessary when nondomestic discharges contain toxic materials or other substances which could adversely affect the WWTP. Most WWTPs designed to treat domestic waste are incapable of treating toxic or concentrated nondomestic discharges. The result is that untreated nondomestic discharges may be incompatible with the WWTP.

Within a treatment plant, incompatibility may create four specific types of problems:

- Inhibition or interference with normal plant operations.
- Accumulation of heavy metals or other toxic substances.
- Pass through of organics and heavy metals.
- Undesirable effects on the sewer system or structures of the treatment plant.

The goal of any pretreatment program is to limit or eliminate problems associated with incompatibility in the WWTP. Reduction of incompatibility decreases the likelihood of plant upset and the discharge of pollutants to the environment.

The ramifications of not controlling nondomestic discharge are far-reaching. Toxic or incompatible discharge to the WWTP can lead to process upsets and violation of effluent standards. Further, the possibility of a buildup of contaminants in the sludge at the WWTP could lead to increasingly higher costs for sludge disposal. Analytical costs associated with sludge disposal could also be increased.

#### **10.1.3 Responsibilities for Nondomestic Pollutant Generators**

The primary responsibility for monitoring the activities of nondomestic discharges is with Base Civil Engineering and Bio-Environmental Section. A periodic survey of all industrial users that are tributary to the WWTP should be conducted. However, each facility manager must be constantly aware of activities in the facility that could lead to increased nondomestic discharges. Any dumps, leaks, or uncontrolled discharges should be reported immediately to the WWTP personnel so they can take appropriate action.

**APPENDIX A**  
**EXAMPLE LABORATORY RECORD, DATA SHEETS**

# **SHAW AFB WASTEWATER TREATMENT FACILITY TOTAL SUSPENDED SOLIDS**

STANDARD METHODS: 1992 18TH EDITION

**COMMENTS:**

**SHAW AFB WATER AND WASTEWATER  
DR2000 / DR100 DAILY LOG AND MAINTENANCE RECORD**

**CALIBRATION LOG FOR  
ORION 97-08 DISSOLVED OXYGEN PROBE**

Method: Instruction Manuals for the Orion 97-08 D.O. Electrode and the Orion SA 520 pH Meter.

## CALIBRATION LOG FOR ORION SA 520 PH METER

1. Place electrode in lower buffer
  2. Press ISO / verify 7.00 / enter
  3. Press cal. / wait for stable reading / enter
  4. Place electrode in higher buffer
  5. Wait / stabilize / press enter
  6. Press slope / functioning properly 92-102%
  7. Press sample / check temperature

**Method:** Instruction manuals for the Orion SA 520 pH Meter and the Orion 91-04 pH electrode with ATC probe.

## **BIOCHEMICAL OXYGEN DEMAND STANDARD METHODS: 1992, 18TH EDITION**

Date In:	Time:	Date Out	Time	
Blank Data: Before Blank:	Bottle #	Initial DO	Final DO	DEP:
	Bottle #	Initial DO	Final DO	DEP:
After Blank:	Bottle #	Initial DO	Final DO	DEP:

### **Analyst:**

**Remarks:**

**APPENDIX B**  
**SUGGESTED MAINTENANCE RECORD KEEPING FORMS**

**PUMP DATA**

PUMP:	EQUIP. NO.:
LOCATION:	
MFGR.:	MODEL:
SIZE:	TYPE:
CAPACITY:	
MATERIAL:	
BEARING NOS.:	
SEAL TYPE / SIZE:	
SERIAL NO.:	DATE INSTALLED: COST:
LOCAL REP.:	PHONE:

**PUMP DATA CARD**

**MOTOR DATA**

MOTOR: \_\_\_\_\_ EQUIP. NO.: \_\_\_\_\_  
MFGR.: \_\_\_\_\_ MODEL: \_\_\_\_\_  
HORSEPOWER: \_\_\_\_\_ SPEED: \_\_\_\_\_  
VOLTAGE: \_\_\_\_\_ AMPS: \_\_\_\_\_  
PHASE: \_\_\_\_\_ HERTZ: \_\_\_\_\_  
SERVICE FACTOR: \_\_\_\_\_ AMB. TEMP.: \_\_\_\_\_  
INSULATION: \_\_\_\_\_ TEMP. RISE: \_\_\_\_\_  
FRAME: \_\_\_\_\_ ENCLOSURE: \_\_\_\_\_  
BEARING NO.: \_\_\_\_\_  
SERIAL NO.: \_\_\_\_\_ DATE INSTALLED: \_\_\_\_\_ COST : \_\_\_\_\_

**MOTOR DATA CARD**

**EQUIPMENT DATA**

UNIT:	EQUIP. NO.:
LOCATION:	
MFGR.:	MODEL:
SIZE:	TYPE:
RATING HP:	CAPACITY:
INPUT RPM:	OUTPUT RPM:
SERVICE FACTOR:	RATIO:
OTHER DESCRIPTION:	
BEARING NO.:	
SERIAL NO.:	DATE INSTALLED:
LOCAL REP.:	COST:
	PHONE:

**EQUIPMENT DATA CARD**

**SPARE PARTS RECORD**

## SPARE PARTS RECORD FORM

SAMPLE INVENTORY CARD

STOREROOM INVENTORY CARD

Item Description -

Item No. \_\_\_\_\_

Isle No. \_\_\_\_\_

Bin No. \_\_\_\_\_

Quantity Maximum \_\_\_\_\_ Minimum \_\_\_\_\_

Reorder \_\_\_\_\_

## INVENTORY INFORMATION

Quantity Used or Stocked	Date	Signed	Quantity on Hand	USAGE OR SUPPLY INFORMATION Usage - Work Order No. Supply - Purchase Order No.

**APPENDIX C**  
**SHAW AFB PROCESS CONTROL/DATA COLLECTION FORMS**

## **SHAW AFB. SETTLOMETER TEST SHEET**

SHAW AFB. SETTLEMENT TEST SHEET										
BASIN NUMBER		DATE		TIME		BASIN NUMBER		DATE		
TIME		OPERATOR		TIME		OPERATOR		TIME		
5 Mins.		30 Mins.		60 Mins.		5Mins.		30 Mins.		
PLOT		PLOT		PLOT		PLOT		PLOT		
1000		20		1000		20		1000		
950		19		950		19		950		
900		18		900		18		900		
850		17		850		17		850		
800		16		800		16		800		
750		15		750		15		750		
700		14		700		14		700		
650		13		650		13		650		
600		12		600		12		600		
550		11		550		11		550		
500		10		500		10		500		
450		9		450		9		450		
400		8		400		8		400		
350		7		350		7		350		
300		6		300		6		300		
250		5		250		5		250		
200		4		200		4		200		
150		3		150		3		150		
100		2		100		2		100		
50		1		50		1		50		
0		0		0		0		0		
MINUTES										
0	5	10	15	20	25	30	40	50	60	
PLOT		PLOT		PLOT		PLOT		PLOT		
20	1000	19	950	18	900	17	850	16	800	
19	950	18	900	17	850	16	800	15	750	
18	900	17	850	16	800	15	750	14	700	
17	850	16	800	15	750	14	700	13	650	
16	800	15	750	14	700	13	650	12	600	
15	750	14	700	13	650	12	600	11	550	
14	700	13	650	12	600	11	550	10	500	
13	650	12	600	11	550	10	500	9	450	
12	600	11	550	10	500	9	450	8	400	
11	550	10	500	9	450	8	400	7	350	
10	500	9	450	8	400	7	350	6	300	
9	450	8	400	7	350	6	300	5	250	
8	400	7	350	6	300	5	250	4	200	
7	350	6	300	5	250	4	200	3	150	
6	300	5	250	4	200	3	150	2	100	
5	250	4	200	3	150	2	100	1	50	
4	200	3	150	2	100	1	50	0	0	
3	150	2	100	1	50	0	0	0	0	
2	100	1	50	0	0	0	0	0	0	
1	50	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	
MINUTES										
0	5	10	15	20	25	30	40	50	60	
TEST RESULTS	OBSERVATIONS		TEST RESULTS		OBSERVATIONS		TEST RESULTS		OBSERVATIONS	
TIME	READING	FLOC FORMATION:	TIME	READING	FLOC FORMATIONS:		TIME	READING	FLOC FORMATIONS:	
0	1000		0	1000			0	1000		
5			5				5			
10			10				10			
15			15				15			
20			20				20			
25			25				25			
30			30				30			
40			40				40			
50			50				50			
60			60				60			

# WASTEWATER TREATMENT PLANT OPERATOR LOG

SHIFT : A      OPERATOR												SHIFT: B      OPERATOR												SHIFT: C      OPERATOR		DATE	
LOCATION	TIME	TEMP.	PH	DO	CL2	LOCATION	TIME	TEMP.	PH	DO	CL2	LOCATION	TIME	TEMP.	PH	DO	CL2	LOCATION	TIME	TEMP.	PH	DO	CL2	Total			
Basin # 1						Basin # 1						Basin # 1															
Basin # 2						Basin # 2						Basin # 2															
Basin # 3						Basin # 3						Basin # 3															
Influent						Influent						Influent															
												Total													Total		
Effluent						Total						Effluent															
Contact Chamber CL2 Residual						Total						Contact Chamber CL2 Residual															
Chemicals																											
Chem.	START WTS LEFT	END WTS RIGHT	FEED RATE	CHEM.	START WTS LEFT	END WTS RIGHT	FEED RATE	CHEM.	START WTS LEFT	END WTS RIGHT	FEED RATE	CHEM.	START WTS LEFT	END WTS RIGHT	FEED RATE	CHEM.	START WTS LEFT	END WTS RIGHT	FEED RATE	CHEM.	START WTS LEFT	END WTS RIGHT	FEED RATE				
CL2			# / DAY	CL2								CL2					# / DAY	CL2							# / DAY		
SO2			# / DAY	SO2								SO2					# / DAY	SO2							# / DAY		
SETTLEABLE SOLIDS																											
5 MINS	30 MINS	60 MINS				5 MINS	30 MINS	60 MINS				5 MINS	30 MINS	60 MINS													
SLUDGE BLANKET LEVELS																											
CL # 1	CL. # 2	CL. # 3				CL. # 1	CL. # 2	CL. # 3				CL. # 1	CL. # 2	CL. # 3													
EQUIPMENT CHECKS																											
Dry Well	Time	Condition				Dry Well	Time	Condition				Dry Well	Time	Condition													
Comments:																											
ANNOtATE BLDG. CLEANED TODAY :																											
INFLUENT	EFFLUENT	RAS																									
COMMENTS :												COMMENTS :												ANNOTATE CLARIFIERS CLEANED:			

## **SHAW AIR FORCE BASE SLUDGE REPORT**

## **SLUDGE TRANSFERRED TO BEDS / PIT**

## **SLUDGE WASTED TO DIGESTERS**

### **FORMULAS:**

**FORMULAS:**

1. TOTAL GALLONS = MAGMETER X 10

### **FORMULAS:**

NO. 1 DIGESTER MULTIPLY TOTAL FEET X 4603 = TOTAL GALS.  
NO. 2 & NO. 3 DIGESTERS MULTIPLY TOTAL FEET X 3670 = TOTAL GALS.

SHAW AIR FORCE BASE WASTEWATER TREATMENT FACILITY  
MLSS/MLVSS

DATE:	TIME:	ANALYST:	
	BASIN #1,2,3	RAS	DIGESTER
SAMPLE VOL. (ML)			
B			
A			
MLSS , MG/L			
INITIAL MLSS , LBS		*****	*****
C			
MLVSS , MG/L			
TOTAL MLVSS , LBS		% VOLATILE	% VOLATILE (DIG)

A\* WEIGHT OF DISH + DRIED RESIDUE

B\* WEIGHT OF DISH

C\* WEIGHT OF DISH + ASH

MLSS , MG/L =  $(A-B)/(10^{-6} \text{ POWER})$       MLVSS , MG/L =  $(A-C)/(10^{-6} \text{ POWER})$

SAMPLE VOL., ML      SAMPLE VOL., ML

TOTAL MLSS , LBS = BASINS #1,2,3 LBS      TOTAL MLVSS , LBS = BASINS #1,2,3 LBS

% VOLATILE =  $(\text{AVG. MLVSS , MG/L})/(10^{-6} \text{ POWER})$   
(AVG. MLSS , MG/L)

STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER,  
TOTAL NONFILTRABLE AND VOLATILE RESIDUE , 1985 , 16TH EDITION .

MCRT , DAYS

SLUDGE VOLUME INDEX

30 MIN. SETTLOMETER

BLANKET (CLARIFIER) #1      #2      #3

GAL WAS SLUDGE

WATER QUALITY

CALCULATE WASTE SLUDGE  
LBS MLSS IN CLARIFIER ( ) 5 DAY MOVING AVERAGE ( ) = SI

DESIRED\_WASTE\_SLUDGE\_(GALLONS)

[ SI ( SLUDGE\_INVENTORY ) ]

DESIRED SLUDGE AGE ( 22 ) RAS CONC MG/L ( ) ( 8.34 )

**SHAW AIR FORCE BASE WASTEWATER TREATMENT FACILITY  
DAILY EFFLUENT ANALYSIS**

## SHAW AFB WASTE PROCESS CONTROL

**MONTH:**

**Sewage Plant**  
**Monthly Safety Check**

<b>Clarifiers</b>	<b>EQ Basin</b>	
Lighting	Steps	
Grating	Grating	
Life preserver	Life preserver	
Steps	Lighting	
Electrical outlet		
Life preserver and line	<b>Chlorine room</b>	
	Cleanliness	
<b>Waste Room</b>	Cylinder	
Cleanliness	Exhaust	
Exhaust Fan	Lights	
Extinguisher	Extinguisher	
Absorbent Material	Chlorine kit	
Electrical outlet	Air pack	
	Electrical outlet	
<b>Paint room</b>		
Cleanliness		
Fuel storage	<b>Sulfur Dioxide room</b>	
Paint storage	Cleanliness	
Extinguisher	Cylinder	
Ventilation	Exhaust fan	
Electrical Receptacle	MSA Respirator	
	ammonia	
<b>Tertiary Filter Room</b>	Leak detector	
Cleanliness	Electrical Outlet	
Hearing protection		
Lighting	<b>Aeration Basins</b>	
Life preserver and line	#1	
Exhaust Fan	Life preserver	
Electrical outlet/cords	Light Fixtures	
	Cable Condition	
<b>Lime Silo</b>	Electrical outlets	
Cleanliness		
Exhaust fan	#2	
Extinguisher	Life preserver	
Outside grating covers	Light Fixtures	
	Cable Condition	
<b>Hose pump house</b>	Electrical outlets	
Exhaust fan		
Cleanliness	#3	
Extinguisher	Life preserver	
Electrical Outlet/cords	Light Fixtures	
	Cable condition	
<b>Digester room</b>	Grating	
Steps	Electrical outlets	
Cleanliness		
Extinguisher	<b>Pump Station</b>	
Hearing Protection	Manhole covers	
Outside Life preserver	Ladders	
A) #1	Exhaust fan	
B) #2	lights	
C) #3	life line	
	sump pump	
<b>Bay area</b>	Floor clean	
Lighting		
electrical outlets	<b>Contact Chamber</b>	
Fire extinguisher	Life preserver	
Cleanliness	Lighting	
<b>Laboratory</b>	<b>Bypass Chamber</b>	
Lighting	Life preserver	
Electrical outlet	Lighting	
Extinguisher		
Cleanliness		
Inspected by		Supervisor

Date \_\_\_\_\_

FMU \_\_\_\_\_ SHOP WEEKLY SAFETY BRIEFING

The Following Subject(s) were briefed at The Weekly safety meeting:

(1) \_\_\_\_\_  
\_\_\_\_\_

(2) \_\_\_\_\_  
\_\_\_\_\_

Personnel listed below were in attendance:

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Briefer \_\_\_\_\_

Signature of Shop Supervisor \_\_\_\_\_

UTILITY SYSTEMS BACKWASH DATA SHEET

**STINFO OFFICE  
ARMSTRONG LABORATORY/OEPP  
2402 E DRIVE  
BROOKS AFB TX 78235-5114**

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**OFFICIAL BUSINESS**